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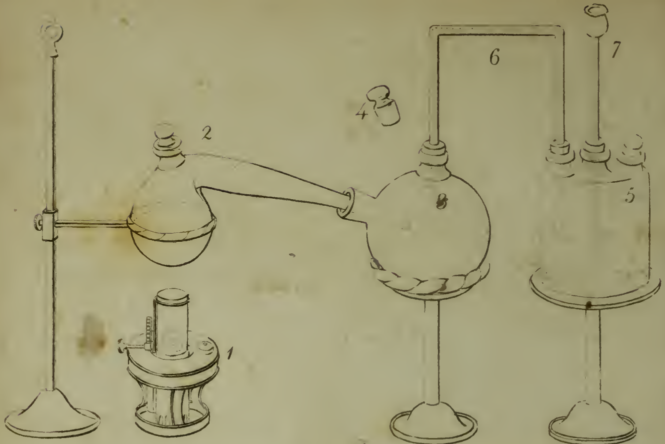

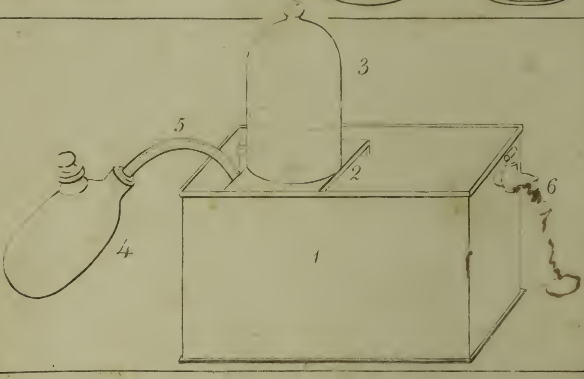

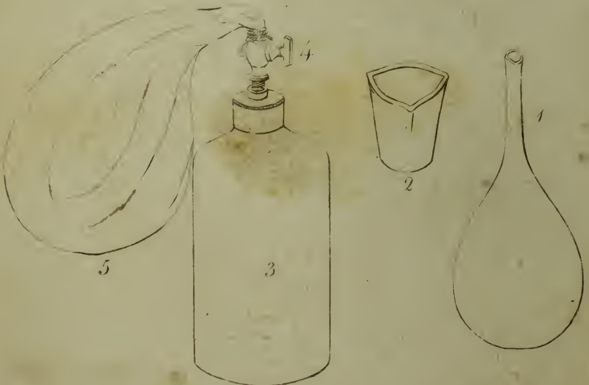

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The Medical Society of London
presented by Dr. John Davidson
1852

RUDIMENTS

OF

CHEMICAL PHILOSOPHY;

IN WHICH

THE FIRST PRINCIPLES OF THAT USEFUL
AND ENTERTAINING SCIENCE

ARE

FAMILIARLY EXPLAINED,

AND

ILLUSTRATED.

By N. MEREDITH.

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PREFACE.

THE claims of Chemistry to general attention can only be a subject of dispute with those who are unacquainted with its nature; the high importance of the facts it exhibits and explains, its intimate connection with the most sublime phenomena of nature, and its no less intimate connection with the most common wants of civilized life, conspire to place it in the foremost rank, not merely of curious, but of useful sciences; there is scarcely an art that is not in some degree indebted to it, and many, such as the manufacture of soap, glass, colours, wines, pottery, together with the processes of distilling, brewing, dying, bleaching, &c. &c. are almost wholly dependant on it; the important science of agriculture, so necessary for the support of human life, and that of medicine, not less so for the preservation of health, have received no inconsiderable improvements from the diffusion of chemical knowledge; without a chemical acquaintance with the natures of the different soils, and of the manures that are or may be employed, the farmer, however industrious, and otherwise intelligent, will be in perpetual uncertainty in the cultivation of his land; and the physician, without a similar knowledge of the agents he employs, will be in danger of prescribing medicines, which, instead of assisting, may mutually destroy each other, and in their operation prove poisonous, rather than medicinal.

Nor is it merely the persons who are more immediately concerned in the several occupations already instanced, and others that might be instanced, to whom an acquaintance with chemical philosophy is desirable, it is so to every person, in every rank of life, not to our own sex only, but to the softer sex also, in their several departments. Who, that possesses the slightest knowledge of Chemistry, can witness, for instance, the long train of errors discoverable in the first lighting, and subsequent management, of a common fire, without wishing that our females, whether in stations supreme or subordinate, understood a little better the theory of combustion? did they but know that *burning* and *combining* with *oxygen* are here one and the same thing, that the air alone is to furnish that oxygen, on which the burning of the fire must absolutely depend, and that no part of the coals can possibly burn where the air cannot reach, they would not, they could not, think of expeditiously raising a fire by overwhelming it with coals; the poker would never be employed as an instrument of vengeance, but only with a view to open a passage for the air to deposit its oxygen, where otherwise it could have no access. Who can reflect on the inconveniences which ladies often suffer for the want of proper water for domestic purposes, and not wish that they were so far Chemists themselves as to know, how easily hard waters, as they are called, may be rendered soft, and thus fitted for the use of the kitchen, the laundry, or the brewery; in short, there is scarcely a domestic operation, from the most important down to the cleansing a vial, in which a knowledge of Chemistry may not be usefully applied. It must be admitted indeed that the inconveniences stated, may be in great measure avoided by persons of sagacity and observation, without becoming acquainted with Chemistry; it may be said that a lady may have learned from observation and experience, that air is necessary to support her fire, without ever having heard of oxygen, or without knowing that the air is a compound, or of what it is compounded—that is to say, a person may in many instances perform an operation with success, without taking the trouble to understand it—a species of consolation not very reputable to an intelligent being. With respect to our own sex, who are at least expected to possess superior information, surely, in the pursuit of knowledge, those objects with which we are immediately surrounded, and on which our health, our life depend, claim our first attention; nor can any character more strange be conceived, than that of a man who should travel to Greece or Rome merely to become master of a language differing from his own, and then pique himself on his learning, while at the same time he is totally unacquainted with the nature of the air he breathes, or the water or other fluids which he drinks, and sits down day after day at his fire side, without at all understanding the principle on which that fire burns.

The numerous experiments in Chemistry are unquestionably among the most entertaining that the whole circle of science can exhibit, and even in a more speculative point of view, its claims are by no means trifling; its pursuits have a natural tendency to withdraw the minds of youth from trifling or dissipating amusements, to impress them with just ideas of the wisdom and goodness of the Creator—they lead to patience of investigation, to accuracy of discrimination, and to justness of conclusion.

In France the importance of the science, as a material branch of liberal education, is universally acknowledged, and not many years have elapsed since its national importance was felt: it will be recollected, that when the English Ministry, not aware, as it should seem, of the resources which Chemistry would furnish, had conceived the hope of preventing the manufacture of gunpowder in France, by stopping the exportation of salt petre to that country, Chemistry obtained a complete triumph over political sagacity, and France was enabled to produce salt petre in abundance, by means which had never entered the minds of her enemies; what Englishman will not feel an ardent wish that his country may not long be behind her rival neighbours.

It seems natural to enquire by what means it has happened, that a science so capable of affording both entertainment and instruction, should have been so long generally, and even now so much, neglected? Among the reasons that may be assigned, without any reflection on the general state of knowledge in our own country, are the following;—Until within these few years, Chemistry has by no means exhibited the features of a regular and well connected science; its facts, though striking, were mostly of an insulated nature, and far from being generally understood, even by Philosophers themselves; while its language, the offspring, in great measure, of random experiments, long continued to be unmeaning, and perplexing beyond any thing that could well be imagined.

Another reason assignable for the slow progress of chemical knowledge, is the general want of apparatus for the performance of experiments, by which alone it can well be acquired; every one is aware that something of this kind is necessary, but very few can conceive how little is absolutely so.

It may likewise be observed, that the *terms* used in Chemistry are at first view discouraging, several of these, as oxygen, hydrogen, nitrogen, are foreign, and to an English ear, harsh and unmeaning;

the reader, however, may be assured that these hard names will very soon become perfectly familiar to him, and when they are become so, will answer their intended purpose full as well as more common ones would have done.

General ignorance of a subject naturally involves in it that of individual; the master of almost every respectable seminary has himself learned the Latin tongue in his youth, and is therefore disposed to consider it as a necessary branch of education for others, and consequently recommends its acquisition to the parents of the youth committed to his charge; but the advantages of Chemistry he has never appreciated, and has therefore no motive to recommend it to others; and the generality of parents themselves are in a similar predicament, even the name of Chemistry is to some forbidding, being too often conceived to relate merely to the composition of drugs and medicines, consequently not of general concern to one sex, and altogether uninteresting to the other; thus beheld through the medium of prejudice and misconception, instead of a garden of fruits and flowers, the imagination sees nothing but a cheerless desert.

Scarcely three years having elapsed since the author himself was totally unacquainted with the science he now presumes to recommend, the difficulties that attended his first attempts are fresh in recollection, as are the pleasures naturally resulting from their removal; and as the greatest discouragements are generally felt at first, when names and things are equally novel, he has thought that some service might at least be rendered to the younger part of the community, by an attempt to remove or lessen some of those difficulties which invariably present themselves to the mind of a young beginner, by furnishing him with a smaller, a cheaper, and, if possible, an easier book than those already published; he has, in consequence of the reception which other attempts have met with, been induced to hope that he possesses at least the talent of writing or speaking plainly—a talent which is certainly not possessed by many persons of far superior information, and which is nevertheless of considerable consequence in the explanation of philosophical subjects.

In making this humble attempt, he has no temptation to depreciate the labours of others, on the contrary, he feels a particular pleasure in recommending to the fair sex the sprightly and instructive "Chemical Conversations," or to those who wish for a more extensive acquaintance with Chemistry, and the facts connected with it, the "Chemical Catechism," to which, for his first information on a subject he now highly values, the author acknowledges himself considerably indebted; Henry's Epitome may on many occasions be useful to the practical Chemist, and Dr. Thomson's work cannot fail to be valued by those who pursue to any extent the study of Chemistry, not only for its discussion of chemical subjects in general, but for its copious account of chemical operations, and the apparatus necessary for performing them. With respect to the faults in the composition of this little work, he has only to say that in many instances it was more easy to discover than to avoid them, consistent with the plan proposed; that he has invariably aimed more at perspicuity than elegance; that he had rather repeat an observation, where perhaps it may not be absolutely wanting, than run the hazard of omitting one where it is. With respect to its form, the advantages attending the catechetical, for the instruction of young persons, has been long since acknowledged; it is equally calculated to awaken the attention and to impress, without fatiguing the memory. It is possible indeed, that the reader may find some difficulty in ascertaining who are the dramatis persona, and may be induced to think that the parts are not always well supported—this, in a novel or dramatic writer, would have been an unpardonable fault, but in the present case it is fortunately of small consequence, or rather it is of no consequence at all, for whether the dialogue is supposed to be carried on between a master and his scholar, between

Mrs. B. and her two fair pupils, as in the Chemical Conversations, or, as in Mr. Parkes' larger, and the present smaller work, between Messrs. Nobody or any body, in either case every one knows that the information or entertainment of the reader is the object aimed at—yes, gentle reader, it is for thee the author and the printer labours, and thy approval must be considered as the highest reward of both; if thou art unacquainted with Chemistry, *some* information and entertainment may be expected from the perusal of this small volume—if, on the contrary, thou art already familiar with all it contains, accept the congratulations of its author, and put it into the hands of some less informed friend or neighbour.

N. M.

RUDIMENTS
OF
CHEMISTRY, &c.

CHAP. I.
ON CHEMISTRY IN GENERAL.
CALORIC, LIGHT, OXYGEN.

WHAT is the design of Chemistry?

The design of Chemistry is to explain the nature of the constituent parts of bodies, the effects that arise from their various combinations, and the laws by which they are governed.

How are bodies usually divided by Chemists?

The general division of bodies is into *simple,* or elementary, and *compound.*

What do you mean by a compound *body?*

A body is said to be a *compound,* when it is made up of two or more ingredients, whether formed by nature, or produced by art; the far greater number of bodies are of this description, and most of them are capable of being divided into their simple or component parts.

Then by a simple *substance, which is of course opposed to a* compound, *we are to understand a substance which consists of only* one *ingredient?*

Yes, and Chemists have agreed to consider all those bodies as *simple,* which they are not able to divide into parts of a different nature, or which give no signs of being compounded.

You have said that the far greater number of bodies are compound, of course the enumeration of those *is out of the question; can you state how many* simple *substances there are?*

The ancients acknowledged only *four* elements, or simple bodies, air, earth, fire, and water. Modern Chemists have *proved* that air and water are compounds; fire appears to be compounded of caloric and light; and, instead of *one,* we have now a long list of *earths;* the number of simple bodies, at present known, amounts to about *forty.*

Are not these usually divided into different classes?

It has been usual to divide them into, five *simple Combustibles,* so called in opposition to oils, wax, &c. which are compound, and in distinction from metals, which are also combustible, but which possess properties peculiar to themselves, *twenty-two Metals,* and *ten Earths,* together with three bodies which do not class with any of these, or with each other, but which will be found to act most important parts in the greater number of the chemical operations, both of nature and art, namely, *Caloric*, *Light*, and *Oxygen*.

Are not the alkalies potass and soda then considered as simple bodies?

They have been always allowed to hold a place among bodies of that class, until the late brilliant discoveries of Mr. Davy, though they have long been suspected to be compounds, and Chemists have often flattered themselves that they were on the eve of discovering their real nature; that honor was reserved for the diligence and penetration of the gentleman already mentioned, who first proved, by experiments, which have been since repeated by the first Chemists in France and elsewhere, that they are *compounds*, metallic oxyds, that is, metals combined with oxygen; thus has that illustrious Philosopher proved, what would hardly have been expected, that oxygen, the acknowledged principle of acidity, is the principle of alkalescence also.

Since it is usual, on entering on the study of Chemistry, to begin with the examination of the simple bodies—What do Chemists understand by the term Caloric; *is it not the same with heat?*

It has been usual in common language to confound, in this instance, cause and effect; when near a fire, we feel the sensation of *heat*, and we very improperly say, the fire is *hot;* whereas, says the celebrated Mr. Locke, *heat* is no more in the *fire* that burns us, than *pain* is in the *needle* that pricks us; by *caloric*, therefore, Chemists understand that extremely subtile fluid which is dispersed through all nature, is capable of pervading all bodies, and which occasions in us that kind of sensation which we term *heat*; it is highly elastic, and has no sensible gravity.

You have described it as being dispersed through nature; do ice and other cold *bodies then contain it?*

Yes, *all* bodies, the coldest not excepted, contain a portion of caloric; its equilibrium, like that of other fluids, may be destroyed, which is the case in proportion as one body is more heated than another, but, in common with all fluids, it possesses this property, that whenever its equilibrium *is* destroyed, there is a constant tendency to restore it, by a communication of caloric from the hot body to the cold one; hence, if red hot iron and ice be placed in the same room, they will both, in a short time, become of the same temperature with each other, and with the air of the room; the ice *acquiring,* and the iron *giving out,* caloric.

Does caloric pervade, or pass through, all bodies with the same facility?

No; there are some that conduct this substance much better than others, as may be easily proved: "While I am writing (says Dr. Franklin in one of his Letters) part of my hand rests on the green cloth which covers my desk, and part on the lock; but though the two bodies are certainly of the same temperature, yet that part of my hand which touches the metal feels *colder,* and really is so, than that which rests on the cloth, because the metal, being a better conductor, carries off the heat of my hand more rapidly than the cloth, and thereby renders that part of the hand which touches it, *colder* than the other.

What would happen if a piece of metal and a piece of woollen cloth were both made hotter *than the hand?*

Since both the cloth and the metal would be disposed to part with their superabundant caloric, the metal, being the best conductor, would part with it the most *readily*, and would feel hottest to the hand, because it would really make the hand so; it is for this reason, that when we have been standing by a ? fire, our *cloaths* do not feel particularly *hot*, while the *money* in our pockets feels almost too hot to be touched.

What is the most general effect of caloric on the different bodies?

Its most general effect is the increase of their bulk; hence, if a bar of iron be accurately measured when *cold*, and afterwards *heated*, it will be found, if measured again while hot, to have increased in length.

Has caloric the same effect on fluid bodies as on solids?

Yes, but in a much greater degree, their particles being more easily separated from each other; every one who understands the principle on which the steam engine is constructed, must be aware how much the bulk of *water* is increased, when converted into *steam* by its union with caloric; and if a bladder nearly empty be closely tied, and held near the fire, the small quantity of air contained in it will be so expanded as presently to fill the whole bladder and cause it to burst with a loud report.

Is the fluidity of bodies owing to the caloric they contain?

The natural condition of all bodies, caloric excepted, appears to be that of a *solid*, their fluidity is owing to the caloric with which they are combined; thus the same body is solid, fluid, or aëriform, according to the quantity of caloric that enters into its composition. Water furnishes a striking instance of this; when below the temperature of 32 degrees, it is a solid, from 32 to 212, a fluid, and when raised above 212 degrees, it becomes an invisible vapour, or steam. Iron and other metals, hard as they are at their usual temperature, yield to this powerful agent, and become fluid as water, while the lightest fluids, even airs or gases, by being deprived of their caloric, become solids; there are scarcely any chemical changes in which it is not, directly or indirectly, concerned, or which are not preceded, accompanied, or followed by a change of temperature. It performs many important operations by virtue of its own properties, unassisted by any other agent, and where the presence of another is required, it gives additional energy to its influence; thus salts, though generally soluble in *cold water*, will dissolve more rapidly, and in greater quantity, if the water is heated.

Are not some bodies disposed to receive and retain a greater portion of caloric than others?

Yes, and this property is termed by Chemists, their capacity for caloric.

How is this proved?

If ice, which has been cooled below 32 degrees, be placed before a fire, and a thermometer immersed in it, the mercury in the themometer will immediately begin to sink, and will not rise again till the ice has attained the heat of 32 degrees, though it must have been all the time receiving caloric from the fire, which proves that the caloric which the ice has received has been absorbed, and as it were *locked up* in it; the caloric thus confined has been termed *latent,* while that which is given out has been called *radiant;* of the quantity of the former contained in any body we have no means of judging, it is the latter *only* that is, or can be, the subject of our observation or experiment.

What is the nature of Light?

With light, as distinct from caloric, we are very imperfectly acquainted, though there are experiments which seem to prove that it is a distinct body; thus Dr. Herschel found that *light* is more *refrangible,* that is, in passing through a prism, its rays are more bent from their original direction; plants, whatever heat may be given them, do not thrive if the light is excluded; light, without sensible heat, is capable of decomposing several bodies, its affinity for oxygen being sufficiently strong to take it from them; hence, if oxygenized muriatic acid be exposed to the action of light, it will be deprived of a portion of its oxygen, and be changed to common muriatic acid: we often feel much heat without the perception of light, and, on the contrary, the light of the moon, though concentrated in the focus of the largest lens, is not accompanied with any sensible heat. Some have supposed that caloric and light are connected with each other, as cause and effect; but which to consider as the cause, and which as the effect, is still, in the present state of our knowledge, an insurmountable difficulty; perhaps at a future period it will be ascertained, that caloric and light (together with electricity, which has sometimes been thought to be a distinct body) are only different modifications of the same substance.

The important part which oxygen also acts in the œconomy of nature, and in chemical operations, is such, that we cannot, as Dr. Thomson justly observes, too soon become acquainted with it.—What then is Oxygen?

It is understood to be (what its name, which is derived from the Greek, and signifies the *generator* of *acids*, imports) the universal *acidifying principle;* most of the various acids have been *proved,* and the rest are, from analogy, *supposed* to be, *compounded* of oxygen and some other substance termed the *base,* from which it derives its name. Thus the nitric acid is composed of *nitrogen* and oxygen, the sulphuric of *sulphur* and oxygen, and so of all the rest.

Does the union of oxygen with another body always produce an acid?

No, it combines with different bodies in various proportions; when, as in its union with metals, it combines with the body in too small proportions to produce an acid, it then forms what is called an oxyd, and even in the production of an acid, the proportions are not always the same; hence, we have sulphuric and sulphurous acid, which differ in the proportions of oxygen they contain.

Is not oxygen a supporter of combustion?

It is in truth the *only* supporter of combustion; all bodies, whether solid, fluid or aëriform, performing that office only by imparting to the burning body the oxygen they contain; it is in consequence of this principle, that the air of our atmosphere, not only supports combustion, but contributes to the support of animal life also, which it is no longer capable of doing, when deprived of it; oxygen is one of the component parts of water, and of various other bodies of vast importance.

Is oxygen found alone, or combined with other bodies?

Though in itself it is a simple body, yet its affinity for various substances is so strong, that we no where meet with it, but in combination with other bodies; the purest form, in which we can obtain it, is that of *gas*, in which it is combined with caloric, which gives it that form.

What is meant by a Gas?

A fluid which is permanently elastic, a kind of air; the air of our atmosphere is a gas, or rather is composed of two gases, every gas is composed of two substances, caloric, and some other from whence it take its name; it is in consequence of its union with caloric, that it continues in a gasious state, instead of being more or less solid. Van Helmont was the first who gave to aëriform fluids the name of gas.

How is oxygen gas obtained for experiments?

It may be procured from a number of different substances: Dr. Priestley, who discovered it in England about the time that the celebrated Scheele made the same discovery in Sweden, obtained it from the red precipitate of mercury, and from minium, or red lead; it may be obtained from nitrate of potass, called salt petre; but the usual and cheapest method of preparing it, is by putting some of the black oxyd of manganese into a retort, and heating it to redness, when the oxygen gas will come over, and may be collected under water in the usual way. If sulphuric acid, diluted with water, be added to the manganese, a greater *quantity* of gas comes over, and with *less* heat.

Can it, when so prepared, be preserved?

It may be kept for any length of time in common glass bottles, if they are closely *corked,* and *inverted* with their mouths *under water.*

You have said that the air owes its salubrity, with respect to animals, and its power of supporting combustion, to the presence of oxygen; cannot oxygen gas be breathed alone, and would it not alone support combustion?

Yes; when so breathed, it has a very exhilarating effect; and if a wax taper, a common brimstone match, or any inflammable substance, is put into it, it burns with a brightness much greater than in common air, as we shall see when we come to consider the nature of combustion.

CHAP. II.

ON SIMPLE COMBUSTIBLES.

WHAT are the names of the five Simple Combustible *bodies?*

Sulphur, Phosphorus, Carbon, Hydrogen, and Nitrogen.

What is the nature of Sulphur?

Sulphur, or Brimstone, the general appearances of which are familiar to every one, is found native in various parts of the world, it was of course very early known, and, as far back as the time of Pliny, was used for the purpose of bleaching wool by exposure to its fumes: when heated to 185 degrees it melts, and if in this state it is poured into water, it becomes of a wax-like consistence; impressions from gems have been taken with it while in this state, which afterwards become perfectly hard; they are of a red colour, and in some respects preferable to those taken with sealing wax.

What is the nature of that powder termed flowers of *sulphur?*

Precisely the same as roll sulphur; it is obtained by heating the sulphur to the temperature of 170 degrees, when it rises in the form of a fine powder, and may be collected in proper vessels; this proccss, which is a kind of dry distillation, is called *subliming*; the ancients seem to give the name of *flowers* to all the products obtained in this way; hence, the terms flowers of *sulphur*, flowers of *zinc*, of *benzoin*, &c.

What are the principal combinations of sulphur?

It unites with *alkalies*, and forms, what are properly called *sulphurets*, but on account of their resembling in *colour* the *liver* of animals, have, agreeable to the absurdity of the old nomenclature, been called livers, which have the property of decomposing water; it is used, in conjunction with charcoal and salt petre, in the manufacture of gunpowder; it is capable, like phosphorus, of two distinct combustions, a *slow*, and a more *rapid* one, the first takes place at the temperature of about 150 degrees, and emits a light so faint as not to be visible, except in a dark place; this may often be seen when a brimstone match is put into a *fire* nearly extinguished, or among coals or cinders which do not retain sufficient heat to ignite the brimstone: the other kind of combustion is well known, and is the subject of continual observation; by this combustion sulphurous acid, to be hereafter described, is formed.

Is sulphur used in medicine?

It is used both externally and internally, and by trituration with mercury, forms the black powder called Ethiops mineral, which has been used with success in the cure of disorders occasioned by worms.

What is the nature of Phosphorus?

Phosphorus, like other important substances, was discovered by accident, in the year 1669, its discovery was made by Brandt, as he was attempting to distil from urine, a fluid that should convert silver into gold: it was for a long time prepared from urine, but the process was both tedious and offensive; it is now made, much more pleasantly and expeditiously, from bones.

If phosphorus is a simple *or uncompounded substance, how can it be said with propriety to be made?*

It is a substance so exceedingly *combustible*, or in other words, has such an affinity for oxygen, that it *burns,* though *slowly,* at the common temperature of the atmosphere; hence, it is never found in nature in an *uncombined* state, but always in combination with, at least, oxygen, forming phosphoric acid; bones contain this acid, and the whole process, which may be seen at large in Dr. Thomson, Parkinson, and other writers, consists in separating it from its oxygen, and changing it thereby from the condition of an acid, to that of simple phosphorus.

What are its principal properties?

The most remarkable is its great inflammability; the heat of the human body is sufficient to make it take fire, when it burns with great rapidity, and brilliancy; it is necessary therefore to keep it in water, and not to handle it, unless when it is wetted or held in a wet cloth: if a small piece of it be rubbed between two pieces of brown paper, it will take fire; it combines with sulphur, and forms a compound so inflammable, that a match dipped in it instantly takes fire.

This compound might be useful when a light was suddenly required, as in the night—How is it prepared?

By mixing together in a small vial, one part of flowers of sulphur, with eight of phosphorus, using no more *heat* than is just necessary to combine them; when a light is wanted, a match is dipped into the mixture and takes fire, or if it fails to do this *immediately*, which is liable to happen after the bottle has been some time in use, it will take fire on rubbing the match (after dipping) on a piece of cork.

From the nature of this substance, it seems to follow that many amusing experiments may be made with it—Can you describe some of them?

In the first place, any characters written with it, or figures drawn, will be luminous in the dark, and will appear to *burn;* if the hand be rubbed on them, the luminous appearance will be communicated to the hands also, and from thence to any other part. If phosphorus be dissolved in boiling olive oil, a kind of liquid fire will be formed; the hands and face may be rubbed with it very safely, and will exhibit a very striking appearance in the dark.

Is any peculiar caution necessary in preparing this liquid phosphorus?

The only precaution required is, to take care that the phosphorus is *entirely* dissolved; since, if any small pieces should remain undissolved, they would be liable to take fire on the skin.

Will phosphorus combine with any other substances besides sulphur?

It will combine with lime, and with it form a very curious compound, which has also the property of decomposing water; if into a glass tube, or, which is still better, a Wedgwood's *earthen* one, closed at one end, a small piece of phosphorus is put, and the remaining part of the tube nearly filled with small bits of lime, and loosely stopped with paper, if that part of the tube which contains the lime be heated until the lime is red hot, and then heat applied to the phosphorus, it will be sublimed, and, combining with the lime, form *phosphuret* of *lime;* when a small quantity of this is thrown into hot water, the water is decomposed, and its hydrogen uniting with the phosphorus, forms bubbles of phosphurated hydrogen gas, will burst and take fire as they rise to the surface of the water.

Is phosphorus used in medicine?

It does not appear to have been used in England, but in France it has been given in small quantities, and, it is said, with great success in cases of mortification: it has likewise been said to produce, for a time, a considerable degree of muscular energy, which, however, has been succeeded by a proportional degree of debility; and it is in general esteemed of a poisonous nature when taken internally.

What is the nature of Carbon?

When any kind of wood is heated red in a vessel from which the external *air* is *excluded,* and kept in that state for some time, it is converted into the well known substance called charcoal; it is completely insoluble in water, and would continue under it for any length of time without decaying; it remains unalterable in the strongest fire, provided the air is excluded. It is not liable to *decay* or *rot,* like wood, and is the most indestructible substance we are acquainted with: incapable of putrifying itself, it prevents or corrects putridity in other bodies.

Might not this singular property in charcoal be employed to advantage?

It actually is so in many instances; charcoal, when pounded, makes the best tooth-powder known; if meat or fish, beginning to putrify, is *boiled,* or even *soaked* for a time in water containing powdered charcoal, the decayed parts are rendered perfectly sweet; on the same principle, putrid water becomes sweet by being mixed with charcoal, and the disagreeable taint which beer casks, &c. often contract is effectually removed.

Is charcoal then to be considered as pure carbon?

So it was thought to be, and therefore Lavoisier gave it that name; but subsequent experiments have been thought to prove, that charcoal is compounded of carbon and oxygen, or, in chemical language, is an oxyd of carbon; plumbago, or *black lead,* is an oxyd of carbon, though supposed to contain less oxygen than charcoal.

Does pure carbon then no where exist?

Yes, pure carbon is found, where perhaps it would least have been expected, in the *diamond*; strange, and almost incredible as it may appear, no fact can be established on more solid proofs, than is the fact that those two substances, *charcoal* and *diamond,* so widely different in colour, transparency, gravity, hardness, and combustibility, differ only in their purity; the one being in a simple state, the other in a state of impurity.

A fact so directly contrary to what would be expected from a comparison of the two substances, require proofs of a very decisive nature—Can you state on what grounds this identity is maintained?

The experiments made to ascertain a point of such importance have been numerous, and their results conclusive; some of the principal are these; they are both completely *combustible,* and when burnt, the product is in both cases *carbonic acid gas,* that is, carbon and oxygen, a given weight of diamond yielding the same quantity of carbonic acid as an equal weight of charcoal, if heated never so much or long, provided the oxygen is excluded, they both remain unaltered, and when iron is heated in contact with charcoal or diamond, they both disappear, and the iron is converted into steel, which is a carburet of iron; these and other experiments, when properly considered, are sufficient to dispel all doubt of the truth of this extraordinary fact.

If such be really the fact, does it not seem to follow, that diamonds may be easily produced by art, since we are so well acquainted with their nature; we have only, as in the making of phosphorus, to take away the oxygen from charcoal, and the substance remaining will be diamond?

It is not impossible but that diamonds may hereafter be formed by art, but though it may at first sight appear much easier to *simplify* than *combine* substances, yet it is often in reality much more difficult; beside, diamond is carbon *crystallized;* to form perfect crystals of many other substances is often, even when we do succeed, a *difficult* and *slow* process, and what length of *time,* even nature herself may require, to form those crystals called diamonds, we are yet ignorant.

Admitting the difficulty of forming diamonds by art *to be accounted for, does it not seem strange, that pure carbon is* so seldom *found in* nature, *when its* oxyds *are so common?*

Mr Parkes, in his Chemical Catechism, has answered this very natural question; he remarks that "aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumine;

that iron exists *every where*, under *every form*, excepting in the state of *purity*, and that the existence of native iron is still doubtful," many are decidedly of opinion that no such thing has ever yet been found.

Have these conclusions respecting the nature of the two bodies, diamond and charcoal, been confirmed by the most recent experiments?

So far as relates to the identity of the two substances, they have been amply confirmed by the very accurate experiments of Mr. Davy, together with those of Messrs. Allen and Pepy's; but, from the fact that charcoal requires as much oxygen for its combustion as diamond, it is inferred by the latter gentlemen, that charcoal is not, as all Chemists until now had concluded, an *oxyd* of carbon or diamond, but carbon itself, and that those two substances differ only from each other "in the state of the aggregation of their particles." Mr. Davy, however, thinks that charcoal, though principally carbon, may be "a very compounded substance." How many more diamonds may be consumed before this question is finally set at rest, is difficult to say.

What is the nature of Hydrogen?

Though hydrogen itself is considered as a simple body, yet we are never able to obtain it in an uncompounded state; the most simple form in which we can examine it, is that of *gas*, in which it is combined with caloric; in this state it is, according to its purity, from eleven to thirteen times lighter than atmospheric air; it is not absorbed by water, of which it is one of the constituent parts; it is very inflammable, and when mixed with oxygen gas, or atmospheric air, it explodes, and water is formed; it is the peculiar property of this gas to burn with *flame*, the flames of lamps, candles, torches, &c. are all owing to the combustion of hydrogen gas, as well as that in our common fires; it is not respirative, and a candle plunged into it is immediately extinguished.

How is this gas obtained?

It may be obtained from different substances: it enters into the composition of oils, rosins, and vegetables in general; it is exhaled during the *putrifaction* of bodies; it may be collected from stagnant muddy water;. it has long been known in mines by the name of the *fire damp;* but from whatever it is obtained, it is always in consequence of the *decomposition* of *water*. The most ready way to procure it is by a direct decomposition of that fluid, by presenting to it some substance capable of abstracting its oxygen; if a red hot poker be plunged into water, the iron seizes a part of the oxygen of the water, bubbles of air rise, which, if caught and examined, will be found to be hydrogen gas; but this, though a very *simple,* is rather a *tedious* way of procuring it; it is therefore in general procured by pouring diluted sulphuric acid on iron, or zinc filings, as will be described when we come to speak of *water:* it has the property of dissolving and holding in solution several substances, as phosphorus, sulphur, and carbon, hence the sulphurated hydrogen, which impregnates the Harrowgate waters, phosphorated hydrogen, &c. it is owing to the different substances held in solution by this gas, that its flame is differently coloured.

How is that gas procured by which it has lately been proposed to light our public streets, &c.?

It is obtained from pit coal, by exposing it to a red heat in a close vessel; any coal may be used for this purpose, but that called *Cannel coal* affords the purest light, the gas as it rises is mixed with a peculiar kind of tar, which, together with the gas, is of a very offensive smell; in passing through water, or even by standing over it the greater part of the tar is deposited, and the gas, comparatively pure, is conveyed by pipes to the several places where it is to be consumed; this gas is called *carburetted* hydrogen, from its holding a portion of charcoal in solution.

Is not this plan an economical one?

The very offensive odour of this gas if it escapes unburnt, and the very great difficulty (as may easily be conceived) of confining a gas so much more subtile than common air, renders the *apparatus*, if properly constructed, very expensive; otherwise the gas itself is procured at a small expence; two pecks of coals would yield a sufficient quantity of gas to support above forty flames for four hours, and produce an effect not to be produced in any other way, and when the gas is all extricated, if any but the Cannel coal is used, there remains a quantity of excellent coak, one half of which is sufficient to supply the fire for the ensuing evening.

Does it then appear probable that this mode of illumination will ever be brought into general use?

By no means, it may answer very well in particular instances, as in large manufactories, &c. but so many and so great are the objections to its *general* use, and so great the mischiefs that would follow even an attempt of that nature, that no disinterested person who has considered the subject, and whose experiments have qualified him to judge of it, can admit even the possibility of success in any attempt to bring it into general use; the countenance that has been given to proposals of this nature, only serve to shew how easily we Englishmen are imposed on, and how perfectly aware of this circumstance, are foreigners in general.

What is the nature of Nitrogen?

Nitrogen, like oxygen, hydrogen, and other substances, is only met with in combination, its most simple state being that of gas, it enters into the composition of animal and vegetable bodies; it is, as its name implies, the basis of the nitric acid, it was formerly called azote, it is a component part of atmospheric air, of which it forms more than two-thirds, it will not support flame; it is in certain cases capable of combustion, and is therefore ranked among the simple combustible bodies, though it cannot be burnt in the common way like hydrogen gas; it is not respirable alone, but it answers, among others, the most important purpose of diluting the oxygen gas of the atmosphere, and rendering it more fit for respiration, &c. than it would be alone. It may be prepared by putting a quantity of iron filings and sulphur moistened with water, into a glass vessel full of air, in the course of a few days all the oxygen will be absorbed and the remainder will be pure nitrogen gas, the properties of which will be more fully considered when we come to speak of the composition of atmospheric air.

CHAP. III.

ON METALS.

It has been stated that the metals, exclusive of those recently discovered, amounted to twenty-two, What are their names?

Gold, Silver, Platina, Mercury, Copper, Iron, Tin, Lead, Nickell, Zinc, Bismuth, Antimony, Tellurium, Arsenic, Cobalt, Manganese, Tungstein, Molybdenum, Uranium, Titanium, Chromium, and Columbium; these differ very much in their properties, and in their importance to society and to the arts; some of them being absolutely necessary to our comfort, if not our existence, while others at present are little more than chemical curiosities; it is perhaps proper to remark, that of this list only the first *seven* were by the ancients admitted as *metals,* though they were acquainted with several substances, the analysis of which has increased *our* catalogue of metals.

Is not the knowledge of metals and their properties of considerable importance in Chemistry?

An acquaintance with the properties of metals is certainly of importance to every Chemist; they are *combustible* bodies, and combustion is a *chemical* process, they form various *chemical compounds*, which exhibit singular properties, and thus become highly interesting, though the various methods of separating them from the substances with which they are mixed in the mine, as well as the art of determining what those mixtures contain, is indeed rather considered as belonging to the minerallogist, and certainly do not come under general observation.

Is that branch of Chemistry termed Metallurgy as much studied as formerly?

The properties of metals are much better *understood* by the moderns, than they were by the ancients, but it must be remembered, that the Alchymists were the fathers of Chemistry, and *their* grand object being the production of *gold*, their attention became almost wholly engrossed by the *metals*; these they tortured in all the ways that science could direct, or imagination suggest; but these delusions being happily at an end, the study of metals is no longer the exclusive object of chemical research; this branch of the science may therefore be said to have found its level.

What are the properties by which metals are distinguished from other bodies?

The properties formerly ascribed to metals, and by which they were said to be distinguished from other bodies, were these; a *lustre*, so peculiar to themselves, as to be termed *metallic-lustre*; a gravity superior to all other bodies; *opacity*; *fusibility*, or the property of melting in the fire; and *malleability*, or capacity of extension by hammering; but in many of these properties they differ as widely from each other, as they do from other bodies, several of them are not at all *malleable;* they are, it is true, *all fusible,* and so is ice, wax, and many other things which do not class with metals, and there is even in this respect, a very wide difference between *platina*, which requires the strongest possible heat to melt it, and *mercury,* which is not only fluid in the common temperature of our atmosphere, but continues so in a degree of cold, much below that at which water itself becomes solid.

But is not their gravity *much superior to all other bodies, and is not this therefore a proper distinction?*

When the number of metals known amounted to *seven* only, it undoubtedly was, for *tin,* the lightest of these, is nearly twice as heavy as *barytes*, the heaviest of all *earthy* bodies; but since the introduction of the new metals, now admitted into all the Systems of Chemistry, the gradation has been much more considerable; arsenic, one of those metals, is only about one fifth heavier than barytes, but *platina* is *four* times as heavy as *arsenic,* and *potassium* and *sodium* are so much lighter than even the lightest of all the earths, that they *swim,* not only on *water,* but on *oil,* that distinction therefore, though hitherto admitted, must now be given up:

their *lustre* and *opacity* seem to be almost all the distinctions remaining, and even in these, some of them are closely imitated by other bodies.

What are the principal properties of Gold?

There is, of course, no metal better known, or its properties better understood, than this; until the discovery of platina, it was considered as the *heaviest* of all the metals; its general appearance is too well known to need describing, it is malleable in a very great degree, a single grain of gold may be beaten out to cover fifty-seven square inches, and an *ounce* of gold on silver wire may be extended to the length of 1300 miles. Dr. Black has made a curious calculation on this subject, he says it would take fourteen millions of those films of gold, that cover fine silver wire, to make up the thickness of *one inch*, while an equal number of common sheets of paper would amount in thickness to three quarters of a mile. It is not very difficult to melt, but it is so *fixed*, as the term is, that though it has been kept for months in a glass-house furnance, it has remained unaltered.

Does gold combine with other metals?

Yes, with most of them, but it has the strongest affinity for mercury, with which it combines very readily; the gilders of metals avail themselves of this property, they form an amalgam, or paste, with gold and mercury, which they spread on the pieces to be gilt, they then expose them to a certain degree of heat, which evaporates the mercury, and leaves the gold behind; in this manner the brass plates and wheels, which compose the inside of a watch, are gilt.

Is gold soluble in acids?

No common acid has any effect on it, but aqua regia, as it has been called, which is compounded of *two* acids, nitric and muriatic, and thence termed the nitro-muriatic, readily dissolves it, so does the oxygenized muriatic, which contains a very considerable quantity of oxygen, and holds it by a slight affinity.

Has not a solution of gold been employed for the purpose of preserving the surfaces of other metals?

Yes, by putting some ether into a solution of muriate of gold, the gold will be made to combine with the ether, and float on the surface; this ethereal gold has been employed by some curious surgeon's instrument makers to defend their instruments from the oxygen of the atmosphere, that is, to keep them from becoming rusty; this preparation was formerly used in medicine, and wonderful virtues were ascribed to it, which are now justly held in ridicule.

What are the properties of Silver?

Silver appears to have been known as early as gold; in the writings of Moses they are mentioned *together*, as constituting part of Abraham's wealth, and this is the first proof that occurs of their being *used*, or even *known*; in its gravity it is inferior to mercury, gold, and platina; in its fixedness in the fire, and its malleability, it yields only to the two latter, to which, in these respects, it is inferior; it combines with sulphur and phosphorus, and with most of the metals.

Is silver soluble in acids?

Yes, it unites very readily with the three principal, and with them forms the nitrate, sulphate, and muriate of silver; on account of the strong affinity of silver for the muriatic acid, these two substances are employed as tests for each other, for they will detach each other from all the substances with which they may be combined; thus, if a few drops of the nitrate of silver are put into any solution containing muriatic acid, a muriate of silver will be formed, which being an insoluble compound, will be precipitated, and become visible in the solution.

Has nitrate of silver been employed in any other way than as a test?

Yes; for though nitrous acid stains the skin of its own colour, *yellow*, and though silver is a *white* metal, and its solution *colourless*, yet it stains the skin black, or a dark brownish purple, approaching to black, it has therefore been used for the purpose of blackening human hair, for staining marble and other substances, and, with the addition of a little gum, as permanent ink for marking linen with a pen.

What are the properties of Platina?

Platina was not known, at least not as a distinct metal, until 1752: its colour is that of silver, but with less brilliancy, it is by far the heaviest of metals, and the most difficult of fusion, as it cannot be melted, when pure, by any furnace; it possesses, in common with iron, the extraordinary property of being joined, or *welded,* as it is called, by hammering two pieces together, when heated to whiteness; it may be *melted* by a large voltaic battery; it is not affected by any acid but the nitro-muriatic; its indestructible nature would render it of very extensive use, especially to Chemists, if it could be procured in large quantities, and at a reasonable expence.

What are the properties of Mercury?

Mercury, or Quick-silver, is one of the metals anciently known, and, from its resemblance to gold in point of gravity, was frequently the subject of experiment with the Alchymists; it is found in large quantities in several parts of the world, particularly in Spain, Germany, and Peru, at the latter of which places many thousands of persons, employed in raising it, are buried under ground, and never suffered to enjoy the light of the sun: it is heavier than all the metals, except gold and platina; it is the only one that is *not combustible;* it is always in a fluid state at the temperature of our atmosphere, but it becomes solid at a certain degree of cold, viz. near 70 degrees below the freezing point, when it may, like the other metals, be extended by the hammer into plates; it is so volatile, that it may be distilled from one vessel to another, like any other fluid body, and if exposed to 600 degrees of heat in the open air, it rises like water in steam, and though this property renders it, as before observed, very useful in the gilding of metals, yet it proves very prejudicial to the workmen, who inhale it; hence, the *watch gilders* and others are most dreadfully afflicted with paralytic affections, notwithstanding the means used by the more benevolent part of their employers to prevent it.

Do the acids act on this metal?

The muriatic acid has no direct action on it, though it may be combined with it by means of the sulphuric acid, when it forms the corrosive sublimate of the shops; the nitric acid dissolves it readily, and when precipitated from this solution, by alcohol, or spirit of wine, it forms the fulminating mercury of Howard.

What are the principal uses of mercury?

Besides its uses in forming an amalgam with gold for gilding metals, it likewise forms an amalgam with *tin foil*, for silvering looking glasses. It is of very extensive use in medicine; triturated with sulphur; it forms ethiops mineral, the corrosive sublimate, before mentioned, forms, with an addition of mercury, the famous medicine called *calomel*, now become almost the right hand of every medical man;

there are likewise the red and white *precipitates* of mercury; when melted with sulphur, and sublimed, a red sulphuret is formed, called *cinnabar*, which, when reduced to powder, is the beautiful red paint called *vermillion.*

What are the properties of Copper?

The general appearances of this metal are well known; its gravity is considerably less than that of silver, being nearly in the proportion of eight to ten. It appears from the works of Homer to have been known, and in use, as early as the Trogan war; before the use of iron, all edge-tools and instruments of war were made of a mixture of this metal with tin, which is very hard; in malleability it is next to gold, and may be beaten into very thin leaves; what is called *Dutch gold* is made by gilding a plate of copper, and then beating it out into leaves.

Have the acids in general any action on copper?

Yes, the nitric acid, by its union with this metal, forms the nitrate of copper, and this salt, when combined with carbonate of lime, produces that fine colour called blue verditer; the sulphuric produces what is called Roman, or *blue vitriol,* but more properly *sulphate* of *copper;* by exposure to the fumes of vinegar, or *acetous acid,* copper is converted into verdegris, or oxyd of copper, and the green colour called mineral green, is a muriate of copper, formed by the action of the muriatic acid on that metal; if a piece of clean iron or steel be dipped into a solution of sulphate of copper, its whole surface will be so completely covered, that it will appear as if turned into copper; if the tin or pewter solder, with which brass candlesticks, &c. are often repaired, be rubbed with moistened sulphate of copper, its surface will likewise assume an appearance of copper.

Of what further uses is this metal?

Its other uses are very numerous, it combines with several metals; a small quantity mixed with gold gives that degree of hardness, without which that noble metal would be of comparatively little *use;* with different proportions of tin, it forms a compound of any given colour, from the deep red of the one, to the white of the other; in combination with zinc, it forms brass, bell metal, cannon metal, and various other useful compounds; its mixtures increase in *hardness* in proportion to the quantity of tin which they contain, but they become in proportion brittle also; that brilliant white metal, of which the specula of reflecting telescopes are made, is a mixture of nearly two parts of copper, to one of tin, it is very hard, but so exceedingly brittle, that, if cold water be poured upon it, when it is only a little warmed by the hands of the workman, it will instantly break.

Is copper at all used in medicine?

No, all its preparations are of a very *poisonous* nature, and hence the conduct of those persons can hardly be too severely *censured,* or even *punished,* who not only neglect to keep *copper* cooking vessels *clean,* but who frequently make use of this poisonous metal to give their pickles and other things a fine *green* colour. Mr. Parkes relates, from the Medical Transactions, an instance of a young lady, who, during the time her hair was dressing, had amused herself with eating samphire pickle, coloured in this way, and who paid for it with her life; this is only *one* instance, among many which might be given, of the sad effects of such a practice, which is the more unpardonable, because *entirely* unnecessary; surely a person's life is not to be thus put in competition with the *colour* of a pickle!

CHAP. IV.

METALS CONTINUED.

WHAT are the properties of Iron?

Iron, which happily is the most *abundant,* is also by far the most *useful* metal, it is indeed by the use of this that all the others are procured and fitted for our use; though seldom, if ever, found *native,* or in a pure state, yet in its combinations it is almost every where present under some form, in stones, in red earthen ware, in plànts, in animals: though it does not appear to have been in use so early as gold and silver, yet that it was so in the time of Moses is indisputable, from his frequent mention of it, and it was probably known much earlier; in its specific gravity it is inferior to copper; it is malleable when cold, but more so when *red hot,* in which state it is easily hammered into any form; it is the only metal, except platina, which is capable of being welded; two pieces, when heated to a white heat, may be firmly joined together, merely by hammering, without solder or rivet; it is the most elastic of all the metals, and possesses such a degree of tenacity, that a wire of one tenth of an inch will sustain a weight of 450 pounds, without breaking; it possesses the singular property of being magnetic, it is not only *attracted* by the magnet, or the loadstone, but the loadstone itself is only an ore of iron. It has so strong an affinity for oxygen, that at a red heat it will take it from water.

Do the acids in general act on iron?

It is acted on by most of the acids, the sulphuric, in a diluted state, readily dissolves it; the substance called *green vitriol*, or *copperas*, but properly *sulphate* of *iron*, is thus produced.

What are the principal uses of this metal?

Besides its use in the formation of an infinite variety of instruments which are well known, its combinations are exceedingly numerous; the salt just mentioned, is used for making ink, and by the dyers in dying black goods; when this salt is calcined, it furnishes the red powder called *colcothar*, or *crocus martis*, which is used for polishing metals and stones, it gives the finest lustre to brass of which that metal is capable, and is the best substance for polishing the specula of telescopes; its magnetic properties furnish the invaluable mariner's compass; plumbago, or black lead, is a carburet of iron, and emery powder, so useful to lapidaries and other artists, is a combination of iron and silex; solutions of this metal in nitrous, muriatic, and acetic acid, are used by calico printers, the beautiful prussian blue is a combination of iron with the prussic acid, and its different oxyds give colour, not only to common bricks, but to the ruby, garnet, topaz, &c. The ingenious Mr. Wedgwood (to whose labours the ladies are indebted for some of their most elegant table furniture, while they have furnished the Chemist and others with vessels and instruments of the first utility,) is reported to have said, that nearly all the fine diversified colours of his pottery were given by the oxyds of this metal only.

Is iron used in medicine?

Iron, according to *Fourcroy,* is the only metal that is not noxious to animals, its preparations are used as tonics, those medicines called *steel* medicines are of this nature, and the *chalybeate* waters owe their virtues to iron; the phosphate of iron, a salt produced by the combination of iron with phosphoric acid, has lately been supposed to be efficacious in those dreadful complaints termed *cancerous;* it were devoutly to be wished that the expectation may be well founded, he would indeed deserve well of the human race who should find a cure for maladies like these.

In what respects does Steel *differ from Iron?*

Steel is a carburet of iron, that is, a mixture of iron with a small portion, not one hundredth part, of carbon; but in consequence of that small mixture, it acquires new and important properties, it is much more *ductile,* its *tenacity* is so much increased, that a wire of steel will support about double the weight which one of iron, of the same diameter, would support; its *elasticity* is greatly augmented, and it acquires the valuable property, peculiar to itself, of being hardened to a great degree, by the simple operation of plunging it, when red hot, into water; it may afterwards be made to acquire almost any temper, a quality which is of the utmost importance in the manufacture of exquisitely fine *edged* or *pointed* instruments, while at the same time, it is rendered capable of taking a very fine polish, of striking fire with flint, and will retain the magnetic virtue for almost any length of time, which iron will not do.

Is there any ready way of distinguishing Steel from Iron?

Yes they may easily, and with certainty, be distinguished from each other, by the application of a single drop of diluted nitric acid; when it has remained on the metal for a few minutes, it may be wiped off; if *iron,* the spot will be of a whitish *green,* but if *steel,* it will be *black,* by the conversion of the carbon into charcoal.

What are the properties of Tin?

Tin appears to have been known very early, it is frequently mentioned in the writings of Moses; its gravity is somewhat less than iron, it has long been considered as the *lightest* of all *metals,* and is mentioned so in most Systems of Chemistry; it is indeed the lightest of all the metals *formerly* known, but is very heavy, compared with some of modern discovery; to the metals already considered, it is much inferior in point of tenacity and ductility, but it is tolerably malleable, as the thin leaves called tin foil will prove; it is flexible, and in bending makes a peculiar kind of crackling noise; it has, even when cold, some affinity for oxygen, and hence it becomes tarnished in the open air, but that affinity, as in other cases, is considerably augmented by *heat.*

What are the uses of this metal?

If tin be heated in an open vessel, its surface is soon oxydated, and a yellow or grey powder is formed, which the workmen call *putty*, and which is used for polishing various metallic articles, optical glasses, &c. when combined with sulphur, by heating in a crucible, it forms a brilliant substance nearly of the lustre and colour of gold, but in flakes, formerly called *aurum musivum*, or *mosaicum*, but more properly sulphurated oxyd of tin, this is used as a paint, and has been sometimes applied to the cushions of electrical machines, instead of the common amalgam of zinc; with copper, as before said, it forms the specula of telescopes, it is used for lining copper vessels for culinary purposes, to defend the copper from the action of acids; though not sonorous itself, it renders copper so, and therefore is mixed with it to form metal for casting bells, &c. it is of great use to the dyer, a solution of it in aqua fortis giving a fine scarlet colour to the dull crimson given by cochineal; it readily amalgamates with mercury, and thus furnishes the metallic coating of our looking glasses; it is likewise of various other uses, too numerous to mention.

What is the nature of those plates called tin plates, *or block tin, of which so many useful vessels are made?*

They are very improperly stiled *tin* plates, being in reality *iron* coated with *tin*: the term white iron, used in Scotland, is somewhat less exceptionable: this property of adhering to iron, which tin possesses, is highly important, it keeps the iron plates from rusting by the action of acids, it gives considerable beauty to their appearance, and furnishes the means of soldering them together in any form, and with wonderful facility.

What are the properties of Lead?

Lead is the last of the seven metals known to the ancients; from its being so frequently coupled with tin in the writings of Moses, one is led to think that it was considered as being nearly connected with that metal; in point of gravity, it occupies the middle rank among the ancient metals, being lighter than platina, gold, and mercury, and heavier than copper, iron, and tin, of which any one may be easily convinced by dropping pieces of gold, iron, and copper into melted lead, the former will sink to the bottom, but the two latter will swim like corks on the surface of the lead: it very soon tarnishes, or is oxydated, by exposure to the atmosphere, but more rapidly when heated; it is malleable, and may be beaten into thin plates, but its ductility and tenacity are but small, and a leaden wire would support but a small weight without breaking.

Do not the oxyds of this metal furnish the painter with several of his colours?

Yes, the white oxyd of lead, or *white lead*, as it is usually called, is made by exposing thin leaves of this metal to the fumes of vinegar; the upper part of a crucible, having a grating a little below the middle, is filled with these leaves loosely rolled round, and beneath the grating vinegar is poured in, the whole being exposed to a gentle heat, resembling that of a hothouse, the rising vapour of the vinegar corrodes, or oxydizes, the lead, and white lead is formed, which is afterwards ground and prepared for painting.

Is this the only instance of the kind?

No; if lead be exposed to the heat of a furnace, it is first, by the action of oxygen, changed to a *grey* oxyd, then to the *yellow*, called massicot, and then to the red oxyd called minium, or *red lead*.

Is not lead of a poisonous nature?

Yes, all its preparations are highly so, as painters, and the workmen in white lead mills, know by sad experience; the vapours of the furnaces where its ore is melted, are said to effect the grass in the neighbourhood, and to kill the cattle which feed on it; but there is one circumstance which must not pass without notice, namely, the horrid practice, too frequent among some of the dealers in wines, &c. of correcting the acidity of their liquors by a preparation of this metal.

What is the nature of this practice?

A solution of lead in acids gives a sweet taste to the liquors with which it is mixed, and hence the acetate, or sugar of lead, has been employed by ignorant or unprincipled dealers to correct the acidity of their wines and cyders: the ignorance of the ancients on this subject, will furnish one, among numberless proofs, of the great advantages of the study of Chemistry.

Since we are indebted to Chemistry for our knowledge of the pernicious nature *of this practice, can it not furnish us also with the means of detection?*

Yes; oyster shells are to be first calcined, reduced to powder, and mixed with an equal quantity of sulphur; the mixture is then to be put in a crucible, and kept in a white heat for a quarter of an hour; when cold, it is to be mixed with an equal quantity of cream of tartar (acidulous tartrite of potass) and boiled in a bottle for an hour; when the water is decanted, twenty drops of muriatic acid is to be added to every ounce of the water; this liquor will detect the least quantity of lead, by precipitating it in a dark coloured powder from the wine which is adulterated with it.

There is a curious preparation, frequently seen in the shop windows of Druggists, called the lead tree—How is it produced?

By dissolving an ounce of sugar of lead in a quart of water in a glass jar; a piece of brass wire, at the end of which a small piece of zinc is suspended, is then let down into the fluid, and the whole corked up tight; in a short time the lead begins to shoot from the zinc downwards, producing the most beautiful appearance of metallic vegetation that can be conceived; it must not, however, be moved when once formed, or it will be in danger of falling to pieces.

What are the properties of Nickell?

It is of a colour between silver and tin; its specific gravity is nearly that of copper; it is malleable, and may be hammered into plates; it is very difficult of fusion, and is attracted by the magnet.

Where is this metal found?

It is found in several parts of Germany, and when first discovered was thought to be an ore of copper, and named by the Germans Kupfernickel, or false copper; its existence as a distinct metal has been doubted by several celebrated Chemists; Dr. Thomson says, "It may possibly be a compound, and so may likewise many other metals, but we must admit every thing to be a peculiar body, which has peculiar properties, and we must admit every body to be simple, until some proof be actually produced that it is a compound;" on this ground we must allow to nickell the honor of being a distinct metal.

What are the properties of Zinc?

It is doubtful whether the ancients were acquainted with this metal, as there is no certain mention of it until the time of the well known visionary, Paracelsus, whose follies ended with his life in the year 1541: it is of a bluish white colour, not very unlike lead, but much more brilliant, and when broken, appears of a crystalline texture; its gravity is nearly that of tin; it is hardly to be termed malleable, though it will flatten a little by a blow of the hammer without breaking; it is easily fused, and, if exposed to a white heat in a crucible, it takes fire and burns away with a very brilliant white flame, covering the mouth of the crucible with a very light white substance, resembling cotton wool, formerly called flowers of zinc.

What are the principal uses of zinc?

It is mixed with copper in what is called *pinchbeck, princes metal,* &c. and in greater quantities for making brass from copper, and hence, if brass be kept in a brisk fire, the zinc is burnt, and the surface of the brass reduced to copper; it forms, when melted, and mixed with a sufficient quantity of mercury to reduce it to the consistence of a paste when cold, the best amalgam for electrical machines, which, however, is much improved by being worked up with a little tallow; when sulphuric acid, diluted with water, is poured on small pieces or filings of zinc, the water is decomposed, as when iron filings are used, hydrogen gas is disengaged, and a whitish salt is at length found at the bottom of the vessel, which has been, foolishly enough, called *white copperas,* but properly sulphate of zinc; a solution of this salt in common water forms a very famous collirium, or eye water, and is perhaps, for slight inflammations of the eye, one of the best that can be used; of late zinc has been applied to a new and important use in galvanic, or more properly, *voltaic* batteries, which are formed by alternate plates of copper and zinc; diluted nitrous acid is interposed between each pair of plates, and the action of this acid, in oxydizing the zinc, produces those powerful electrical effects by which Mr. Davy has made his surprizing discoveries.

What are the properties of Bismuth?

Its specific gravity is between those of silver and copper; it is one of the most fusible metals, and it renders other metals that are mixed with it more easily fusible; a mixture of equal parts of lead, tin, and bismuth, is so very fusible, that it may be melted on paper over the flame of a lamp; its colour is a kind of brownish yellow, and its texture, when broken, not unlike that of zinc; it is not at all malleable, but, on the contrary, may be powdered by the hammer; its singular property of expanding as it cools, renders it useful in giving a sharp impression to printers' types.

What is the preparation called Magistery of Bismuth?

When the salt called nitrate of bismuth is formed by dissolving the metal in nitrous acid; it does not dissolve in water, as the other salts do, but is precipitated in the form of a white powder, this is the white oxyd formerly called magistery of bismuth; its beautiful white has occasioned its use, by the ladies, as a paint for the skin; but, not to mention the bad effects of almost every substance rubbed on the skin, in stopping up its pores, a lady should be very cautious in using this beautifier, lest, by exposure to any putrid effluvia, or sulphuretted hydrogen, such as the Harrowgate water abounds with, or even by sitting too near the fire, her lovely *white complexion* should be suddenly turned to a *copper brown;* an instance of which is related by Mr. Parkes in his Chemical Catechism.

What are the properties of Antimony?

It is in colour of a greyish white, and when broken has a crystallized appearance; its specific gravity is rather less than that of tin; it is very brittle; the addition of a small portion of it has been found to give additional compactness to the specula of reflecting telescopes; the substance usually called crude antimony, which is used by stationers to black the edges of cards and paper, is a sulphuret of the metal, that is, a combination of sulphur with antimony: the Eastern ladies formerly used this sulphuret to give a beautiful black to their eye-lids; it was thus that Jezebel, of whom we read in 2 Kings ix. 30. adorned herself, and not by painting her *face,* as we have translated it.

Is Antimony used in medicine?

Yes, the celebrated *fever* powder of Dr. James is a preparation of it, and so, as its name implies, is its imitation the *pulvis antimonialis* of the shops; emetic tartar is also an antimonial preparation.

What are the properties of Arsenic?

In its metalline state it is very *brittle*, and may easily be reduced to powder in a mortar; its specific gravity does not much differ from that of tin; it is used for whitening copper; and brass pins, such as ladies use, are whitened by it; it gives additional whiteness and compactness to metallic specula; it is useful in the preparation of several colours for the painter, the dyer, and the calico printer; the orange colour called *orpiment*, the fine green called *Scheel's green*, and the king's *yellow*, are all, with several others of less note, preparation of this metal; the common white arsenic, which is an oxyd of this metal, is well known; it is esteemed a most dreadful poison, and so in fact is every powerful medicine, if taken in too large quantities, but it has for some time been pretty generally employed, and with great success in small quantities, in the cure of intermitting fevers, though the faculty, on account of the strength of popular prejudice, are cautious in avowing the practice.

What are the properties of Cobalt?

Cobalt, as a metal, does not appear to have been yet applied to any use, though it will combine with several of the other metals; it is of a whitish grey colour, sometimes with a shade of red or pink, is rather heavy, but very brittle, and of little brilliancy; it is obtained from a mineral called Zaffre; it is principally valuable on account of its *oxyd*, which gives a very fine and permanent *blue* colour, and has for more than two centuries and a half been employed to colour glass; the blue colour called *smalt*, or commonly *powder blue*, which is used by painters, by the laundresses, mixed with starch, to colour their linen, and by paper makers for the colour of their paper, is *flint glass*, coloured by this oxyd, and ground to a fine powder; a coarser sort of this is sometimes used, as a ground, by sign painters.

Has not cobalt been used for preparing a sympathetic ink?

Yes, a beautiful and very curious preparation of this kind is made, according to Dr. Henry, by digesting in a sand heat for some hours one part of *cobalt*, or better still of *zaffre*, with four parts of nitric acid; to the solution add one part of muriate of soda (common salt) and dilute with four parts of water; characters written with this solution are perfectly invisible when cold, but on gently warming the paper appear of a fine blue or green, according to the purity of the metal employed, these when cold disappear again; the experiment may be repeated as often as desired, provided the paper is not too much heated, for when that happens the colour does not afterwards entirely disappear: it is said that landscapes, representing a *winter* scene, have been drawn on a fire skreen, the leaves, grass, &c. have been drawn with this ink, and of course were invisible, until the skreen has been brought near the fire, when the barren trees have been immediately covered with leaves, as if by magic, the ground has become green, and the whole has assumed the appearance of spring.

What are the properties of Manganese?

Manganese is a metal of comparatively modern discovery; it is of a dusky white colour, of some lustre, hard, brittle, and very difficult of fusion; its attraction for oxygen is so great, that it is never found in nature in a metallic state; what is sold under the name of manganese is the black oxyd of that metal; this oxyd is a valuable treasure in the hands of the young Chemist, as it enables him, at a small expence, to procure a large quantity of oxygen gas, and thereby instruct and entertain himself with some of the most important and most beautiful experiments that the science of Chemistry affords.

Is not the curious substance called camelion mineral prepared from manganese?

This preparation, so called from its changing the colour of the water in which it is dissolved, is a highly oxydized manganese with potass; the method of preparing it is differently described by different authors; that given by Mr. Parkinson, in his Chemical Pocket Book, is perhaps the best. Melt in a crucible one part of the native (the common black) oxyd of manganese, and three parts of nitrate of potass (salt petre) "till no more oxygen gas is disengaged;" there is, however, some difficulty in making this compound succeed, perhaps owing to the oxygen gas not being *all* driven off, which requires a strong heat, and perhaps for want of attention to what Mr. Parkes has observed, that if any *sulphur* is suffered to come in contact with it, the whole is spoiled; when a little of this compound is thrown into a glass of water, the solution is first *blue*, then *green*, then *blue* again, then *reddish*, *brown*, *black*, and at last *colourless*.

What are the properties of Tellurium?

Of Tellurium, and the six remaining metals, little more than their names and appearances are known; the same remark may be extended to several other metals discovered, or thought to be discovered, by different persons, no less than four of which have occurred in the ore of platina; Chemists are certainly much indebted to the patient and laborious researches of those gentlemen who have explored the natures of these substances, but they do not at present exhibit properties sufficiently interesting to engage that attention of the young Chemist, which may more profitably be directed to other objects.

CHAP. V.

ON EARTHS.

WHAT are the names of the ten Earths?

Barytes, Strontian, Lime, Magnesia, Allumine, Yttria, Glucina, Zirconia, Augustina, Silica.

By what properties are the earths distinguished from other bodies?

They are, *generally* speaking, not soluble, or but slightly so, in water; have little or no taste or smell; they are *fixed,* or incombustible, in the fire; their specific gravity never exceeds five times that of water; to which Dr. Thomson adds, that when pure, they assume the form of a white powder; though they possess these properties in so many different degrees, that there is some difficulty in knowing how to class them; accordingly some of the French Chemists have put barytes and strontian among the alkalies, while Dr. Thomson calls in question their title to this distinction, unless lime, and magnesia also, are invested with the same.

What are the properties of Barytes?

It is the heaviest of all the earths, being more than four times as heavy as water; its present name, which is from the Greek, signifies *heavy;* it was formerly called ponderous spar; it resembles the alkalies, with which it has been classed, in its effects on vegetable colours, its causticity, and in the degree of its solubility in water, for boiling water will dissolve half its weight of barytes; but it is distinguished from the alkalies by not being fusible in the fire.

Is barytes found native, or is it prepared by art?

It is always found in combination with an acid, most frequently the *sulphuric,* for which it has so strong an affinity, that it is capable of detaching it from every other substance, and thus it becomes an admirable test for the presence of that acid: it is separated from the acid naturally combined with it, by exposure to heat in a crucible with charcoal, and afterwards with nitric acid, and when pure, very much resembles lime, though it has a more caustic taste; it may be slaked by pouring on water, when it exhibits nearly the same phenomena as lime, only it absorbs the water more rapidly, and there is a greater disengagement of heat than in the slaking of lime; it is sometimes used medicinally, though if taken in any considerable quantity, is said to be highly poisonous; it forms a permanent white paint, and has the property of tinging flame with a yellow colour.

What are the properties of Strontian?

Strontian, so called from a lead mine in Argyleshire, Scotland, resembles so nearly the last earth, for which it was at first taken, that little need be said on its properties; its gravity, however, is less than that of barytes, and it is less soluble in water; it differs from that earth in giving a *purple* colour to flame, instead of yellow. Mr. Parkes indulges a hope, arising from its abundant existence, that it may hereafter be found to possess valuable properties, for he observes, and certainly with justice, that the Author of nature has formed nothing in vain.

What are the properties of Lime?

Lime has been long known, it was used by the ancients in medicine, probably for the same purposes as we employ magnesia; but its most important property is that of forming a cement for building, for which purpose it is *now* used, and has been used from time immemorial; it is one of the alkaline earths, and therefore possesses, in common with them, the property of effervescing with acids, changing vegetable blues; it has a burning taste, and is somewhat corrosive.

Is lime a natural or artificial body?

It is no where found naturally in the state of lime, that is, in an uncombined state, but is always in combination with carbonic acid; by its union with that acid, it forms chalk, marble, limestone, &c. and the process of making lime consists in separating that acid from it by burning; but so strong is the affinity of these two substances for each other, that if the lime, when burnt, is not kept from the air, it will imbibe carbonic acid from it, lose most of its characteristic properties, and be reduced to chalk, or carbonate of lime, again.

Will it not unite with other substances besides carbonic acid?

Yes, its affinity for water is well known; if left exposed to the air, it abstracts its moisture, and crumbles to pieces; it is in a very small degree soluble in water, requiring 500, or, according to some, 700 times its weight of water to dissolve it; it forms with fluoric acid the beautiful substance called Derbyshire spar; with sulphuric acid plaster of Paris; it is the basis of the *shells* of *fish,* and of *animal bones;* it combines with sulphur; with phosphorus it forms a curious substance called phosphoret of lime, which has the property of decomposing water, and with its hydrogen forming bubbles of phosphorated hydrogen gas, which take fire on reaching the surface of the water.

What are the properties of Magnesia?

Magnesia was introduced about the beginning of the eighteenth century, as a medicine; its preparation was kept a profound secret, and it was, as usual in those cases, magnified as a cure for all diseases; it is a white powder, very soft to the touch, has scarcely any taste, and is destitute of smell; its specific gravity is about half that of barytes, and it is so little soluble in water, that it requires near 8000 times its weight to dissolve it.

Is it a natural or an artificial production?

It is found, combined with sulphuric acid, in sea water, from whence it is frequently obtained, after the common salt has been separated from it; likewise in several springs, and from the circumstance of some of those springs being discovered in the neighbourhood of Epsom, the sulphate was called *Epsom salts;* the process of obtaining the magnesia from this salt is extremely simple; when the salt is dissolved in water, half its weight of potass is added; the sulphuric acid combines with the potass, and the magnesia falls to the bottom, and is taken out, washed, and dried.

Has magnesia been applied to any useful purposes?

Its use in medicine is considerable; it is an alkaline earth, and possesses, in common with all those bodies, the property of correcting acidities, while the use of it is not attended with those inconveniences which frequently attend the use of the other alkaline substances; it is useful to the Chemist, and to the manufacturer of porcelain, and is an excellent antidote against the mineral poisons.

What are the properties of Alumina?

This earth is the pure part of clay, or clay freed from the impurities with which it is usually found, and, together with its salt, *allum,* or sulphate of alumina, appears to have been known to the ancients; though they were ignorant of the component parts of allum, they knew its properties, and employed it in dying; they availed themselves of the well known property of alumina in hardening in the fire, and formed a variety of vessels with it; its affinity for greasy substances, from whence it derives its cleansing property, appears likewise to have been early known; it is not soluble in water, though it readily mixes with it, and it does not effect the vegetable colours.

Is not alumina frequently met with in combination with other bodies?

Yes, *fullers' earth* is a mixture of clay and silex; *ochre,* a well known yellow powder, used as a paint, is alumina and oxyd of iron.

Are earthen vessels made of alumina only?

No, its property of *contracting* in the fire, renders it unfit to be used alone, as the vessels formed of it would crack in baking, to prevent which it is mixed with various proportions of sand, according to the purposes for which it is wanted.

Are the remaining earths of equal importance with those already considered?

With the exception of silex, they are to be regarded as little more than chemical curiosities: of Yttria, Glucina, Zirconia, and Augustina, we know but little except their names, and the very existence of the last appears to be doubtful; silex, however, is a valuable earth.

What then are the properties of Silex?

Silex is that earth of which flint is formed; pure sand is silex; quartz, or rock crystal, is composed of silex; so are, more or less, all the precious stones; its great importance will appear when it is considered that the beautiful and highly useful article glass is formed of it; it has no taste, or any alkaline properties; it is not of itself fusible in the fire, but on being mixed with an alkalie, readily runs into glass; the asbestos, of which the famous incombustible cloth was made, is principally silex; and, while it enters into the composition of those stones which have obtained the appellation of precious, the firmness and durability of our public roads are owing to it; it enters into the composition of earthen wares of all sorts.

CHAP. VI.

ON THE ALKALIES.

HAVING considered the properties of all those bodies which, in the present state of chemical knowledge, are considered as simple, what compounds will come most naturally to be considered?

Though this point, as Dr. Thomson observes, is luckily not of much consequence, yet the peculiar circumstances of the alkalies, arising from their near relationship to several of the earths, and their having been themselves, until very lately, considered as simple bodies, seem to give them some claim to our next consideration.

How many alkalies are there?

Three, Potass, Soda, and Ammonia; the two former of these are generally seen in a solid or crystalline state, the latter in a fluid one.

Since these have been considered as simple *bodies, we are to conclude that they are not* prepared *by* art, *but are found native?*

This does not by any means follow; there are several bodies considered as simple, which are never found in *nature,* but in a state of combination with other bodies, from which the art of *Chemistry* is employed to *separate* them; the curious substance called phosphorus is an instance of this, the art of *making* which, consists in *separating* it, by an intense heat, from the substances with which it is naturally *combined*.

How then are the alkalies obtained?

Potass and *Soda* are both obtained from the *ashes* of burnt *vegetables*, by washing them in water, and afterwards pouring off the water, and evaporating it, when the alkalie is found at the bottom of the vessel; it is, however, by no means in a pure state, but is mixed with several other substances; from *some* of these it may be purified by exposure to a red heat, but it is still combined with carbonic acid, which blunts, and almost *destroys*, some of its properties; it may in great measure be separated from that acid by boiling with quick-lime, which has a very strong affinity for the acid; this is the state in which it is commonly sold, and in which it is sufficiently pure for the generality of experiments; to render it *perfectly* pure, requires a very difficult and expensive process, and when made so, it must be carefully preserved from the air, or it will again imbibe carbonic acid from it, lose its causticity, and become unfit for most experiments; there is indeed another circumstance which renders it necessary to keep those alkalies from the air, namely, their strong affinity for water; if exposed to the air they would soon *deliquiesce*, or melt.

Is there no difference in the preparation or properties of the two alkalies?

The *potass* is prepared from vegetables which grow on the *land,* but *soda* is obtained from the ashes of *marine* plants; formerly their properties were supposed to be exactly similar, but it has now been ascertained that there are some circumstances in which they differ, which, however, it is not necessary at present to state, as they perfectly agree in their general characters.

How is the other alkalie called Ammonia *procured?*

It may be procured by distillation from various substances; it obtained the name of ammonia from its being distilled from *sal ammoniac*; the horns and hoof of animals yield it, and from the circumstance of the horns of the hart having been sometimes used, it has vulgarly been called *hartshorn;* in distillation it rises in the form of *gas,* but is rapidly absorbed by the water in the receiver, and forms with it *liquid* ammonia, or spirit of hartshorn.

How have the alkalies been divided by Chemists?

Into fixed and volatile, and into mineral and vegetable; the ammonia is certainly *votatile,* its natural form being that of a gas, and the potass and soda have some claim to the title of *fixed,* because they are not dissipated but by a *red* heat; but the distinction between mineral and vegetable, being unfounded, is now laid aside.

What are the properties *of the alkalies?*

We must, once for all, observe with Dr. Thomson, that our classifications, however necessary, are artificial; "nature does not know them," and often refuses to conform to them; it cannot therefore be expected that the alkalies, any more than the acids, and other classes of bodies, should agree in *all* their properties; it is sufficient for our purpose that they do so in their *general* ones: the principal characteristics of alkalies are these, 1. they have a hot and bitter taste, and when pure are highly *caustic;* 2. they change the vegetable blue colours to green; if a piece of unsized paper, coloured with litmus, (or with the juice of red cabbage, which gives a dull blue colour and affords a more *delicate* test than litmus) if this paper be dipped in an alkaline solution, it will be changed to a bright *green;* an infusion in hot water of the flowers of mallows will answer the same purpose; there is another very delicate test for alkalies, which has lately been much used, viz. paper stained by *turmeric*; this is of a bright yellow, and on being dipped into any alkaline solution changes to a brown: 3. they occasion an *effervescence* when mixed with acids.

What is meant by an effervescence?

An appearance somewhat similar to what is termed boiling; when an acid and alkalie are mixed, provided one of them is in solution, a brisk kind of motion is seen in the mixture, small bubbles of air cover the surface, and a hissing noise is heard; whenever this happens, on putting an acid into any solution, it indicates that the solution contains some substance of an alkaline nature.

Are not the alkalies of great use in the various arts?

Yes, their uses are numerous and important; in the manufacture of that elegant and useful article *glass,* the alkalie acts a very distinguished part; silex, of which glass is made, will not melt of itself, but becomes fusible on mixing with an alkalie; for this purpose the preference is given to soda, as it is found to fuze the silex most readily; the same preference is given to this alkalie over potass for another reason, in other cases, namely, because it is less corrosive, and therefore less liable to injure the linen, &c. when it is used in dying, bleaching, &c. alkalies have the very useful property of rendering oils and fat miscible with water, and thereby forming soaps; for this purpose potass is preferred in the manufacture of soft soap, and soda in that of hard, from an idea that the latter gives more firmness to the soap than the former.

Is it not to the alkalie that soap owes its detersive or cleansing quality—why then are the oils or tallows added?

The caustic nature of the alkalie, if alone, would injure the finer sorts of linen, as well as the hands in using, therefore the tallow or oil is added to render it more mild, and more fit for general purpose.

Can the alkalies only be obtained from the ashes of burnt vegetable substances?

They may be obtained by different processes from other combinations; that vast depository the *sea,* contains immense quantities of *soda*, for table salt, which is obtained from it, is soda, combined with muriatic acid.

Are the combinations of the alkalies numerous?

Yes they combine with all the acids, and form a numerous class of salts, which, agreeably to the excellent plan of the present nomenclature, are named from the two substances which form them, as the nitrates of ammonia and of potass, sulphate of soda, &c. these salts were formerly called *neutral* salts, as being neither acid or alkaline, but that term is now laid aside; the acid which they are always *naturally* combined with, and from which, as already observed, it is difficult to separate them, is the carbonic, with this they form carbonate of potass or soda.

What is the nature of the volatile alkalie, ammonia?

In its general properties as an alkalie, it agrees with the fixed ones; that very useful salt called sal ammoniac, is a muriate of ammonia, that is, ammonia combined with muriatic acid; ammonia is exceedingly useful in medicine, and in various arts; in its combination with carbonic acid, it assumes a concrete form, and beautiful white colour, and is then the salt called sal volatile, contained in the ladies' smelling bottles.

Having finished our examination of the metals, alkalies, *and* earths, *it seems now proper to advert more particularly to the recent discoveries of Mr. Davy, which bear so near a relation to those bodies; and first of the alkalies, for these, you have said, have proved to be* compound—*What then is the nature of their composition, and the discoveries relating to them?*

The alkalies and earths have long been the subjects of suspicion; though permitted to hold their rank among the simple substances, yet it has been supposed by many of the first Chemists that they were compounds, and accordingly numerous attempts have been made to decompose them, nay, some French Chemists of eminence had gone so far as to announce their decomposition; but their experiments were not satisfactory, nor did they seem to suppose that the *nature* of the *compound* had been ascertained: at length, our justly celebrated countryman, Mr. Davy, after numerous well conceived and accurate experiments, succeeded in obtaining from the two alkalies, two distinct metallic substances, one of which he called Potassium, and the other Sodium.

What are the properties of those metals?

Though different in some instances, not necessary at this time to notice, their general characters are the same; their specific gravity is so small, that they swim, not only on *water*, but on *oil;* their consistency is between that of a fluid and a solid, or like that of soft wax; their affinity for oxygen is so great, that they readily take it from water, and burn with rapidity the instant they are thrown on its surface, as they do on that of ice; and though carbonic acid gas extinguishes the flame of that very combustible substance hydrogen gas, these metals will burn in it with a splendour, which, though different in colour, is little inferior to that of sulphur in oxygen gas; in consequence of their strong affinity for oxygen, even at the common temperature of the atmosphere, it follows that they are not to be met with naturally in their *metallic* state, but in the condition of an *oxyd;* potass is an oxyd of potassium, and soda of sodium.

By what means was the decomposition of the alkalies effected?

Mr. Davy accomplished it by the *galvanic,* or more properly *Voltaic* battery, by the force of which he was enabled to expel the oxygen from the potass and soda, when their metallic bases appeared; their affinity for oxygen is such, that they cannot be preserved, if exposed to the air, and are therefore always kept under fresh distilled naptha.

Is there no other method of decomposing the alkalies?

Yes, the French Chemists, having heard of the discovery, had recource to another method, which has succeeded; it is the same as that by which water is decomposed; some iron turnings are put into the middle of a gun barrel, a quantity of potass placed in a tube at one end is made to drop slowly down on the iron turnings, while in a white heat; the potass is thus deprived of its oxygen, which combines with the iron, and the potassium is found at the other end of the gun barrel.

The discovery is certainly a very curious one; is it likely to be of extensive utility?

It is not possible, in the present state of things, to ascertain its importance, but it is easy to conceive that such powerful agents may hereafter be employed to very great advantage in a variety of ways, which cannot now be pointed out. It may be proper to observe, that, notwithstanding the difficulty in operating on the volatile alkalie ammonia, there is good reason to conclude that the base of that is metallic also.

Have any of the earths *been decomposed?*

Yes, Mr. Davy has also succeeded in decomposing, by the Voltaic battery, the four *alkaline* earths, *Barytes, Strontian, Lime,* and *Magnesia,* and has produced metallic substances from those also, to which he has given the names of Barium, Strontium, Calcium, and Magnium. Mr. Davy supposes, and the idea is plausible and beautiful, that though, for obvious reasons, these metals cannot exist at the *surface* of the earth, yet they may be buried *under* it; and, if this be admitted, it is not difficult to conceive that by the contact of water, or some other substance capable of imparting oxygen to them, they would be *inflamed*, and bursting from their confinement, would occasion *earthquakes*, and other tremendous effects, which have not hitherto been accounted for.

CHAP. VII.

ON CHEMICAL AFFINITY.

IN any attempt to understand the science of Chemistry, is it not of importance to be well acquainted with the laws of Affinity?

Yes, of the greatest importance, because all the changes we are capable of producing, depend on those laws; and we are therefore unable to perform any thing ourselves, or understand what is every day passing before our eyes in *nature,* or in *chemical experiments,* without attending to the laws of affinity, by which they are invariably governed.

What do you understand by the term Affinity?

The *disposition* which certain bodies, of *different natures,* have to *unite* when mixed together; and by which they form substances different in their appearances and properties from those of which they are composed.

Is the term affinity of the same signification with that of attraction, so often used by Philosophers?

No, the word *attraction* is meant to express the tendency of certain bodies to *approach* and *adhere* to each other, but without forming any real *union,* or producing any *change* of substance; attraction frequently exists between bodies of the *same nature;* but the term affinity, is meant to express the tendency of bodies of *distinct* and *opposite* natures to enter into union, and form, by the union, new bodies.

Have all bodies an affinity for each other?

No, some have no tendency to unite with each other; while, on the contrary, others are no sooner brought together, than a violent action ensues, and they are perfectly, and sometimes immediately, united.

Can you produce any instance of that difference?

Yes, if sand and water are agitated together never so violently, they do not at all *unite,* but, when suffered to rest, are found perfectly separate from each other; the same will take place when oil and water are mixed together; but if any kind of *salt* be thrown into water, it will be *dissolved,* will disappear, and be united to the water; or if a piece of copper be put into *nitrous* acid, or aqua fortis, a violent effervescence will ensue, accompanied with striking appearances, the copper will be dissolved, and a new substance, called nitrate of copper, will be the produce of its union with the acid.

Is the force *of this principle, which you term affinity, always* equal?

No, between some bodies the affinity is very weak, while others are so strongly held together by it, that it is exceedingly difficult to separate them.

Is not the knowledge of this difference *of great importance to Chemists?*

Yes, so important that it constitutes the very foundation of chemical science, since without it none of those changes, consisting of composition and decomposition, could be either *performed* or *understood.*

By what means do Chemists effect a change in the body under examination?

By presenting to the substance they intend to operate on, some other substance which has a stronger affinity for one of its component parts than that by which they are held together, and which will therefore detach it from the original compound.

Can you give an instance of this difference of affinity, and its effect, as now stated?

Yes; if you take spirit of wine, in which a very considerable *proportion* of camphor has been previously dissolved, it will in the first place afford an instance of simple affinity, for the spirit will be perfectly transparent, and the camphor invisible; if now clear water be poured in, the *different degrees* of affinity will be exemplified, for the spirit having a *stronger affinity* for the *water* than it has for the camphor, will unite with it; the camphor will be disengaged, and fall in the form of a white cloud to the bottom of the vessel; or the same may be shewn by dissolving common salt in water, and then pouring in spirit of wine, when the salt will fall to the bottom of the vessel, as the camphor does in the first experiment.

It appears then that all the operations of Chemistry are conducted on these principles?

Yes, the original combinations, to which the forms and properties of the bodies were owing, being thus destroyed by the action of new, and more powerful affinities, new substances are produced, differing entirely, both in appearances and properties, from those out of which they were formed; thus colours are produced and destroyed, solids become fluids, and fluids become solids; corrosive substances, by their action on each other, become mild, and mild ones become corrosive.

Name one or two of the most striking instances in which a change of colour *is produced by chemical agency?*

If I pour boiling water on a piece of red cabbage, it will, when poured off, have little or no colour, but if I pour some of this water into two glasses, and then pour into one a solution of potass, or any other *alkalie,* it will turn of a beautiful *green;* while on the contrary, if I pour into the other a small quantity of sulphuric, or any other *acid,* it will appear of a lively *red* colour.

Can the colours, thus prepared, be again changed or destroyed?

Yes, for if I now pour the *green* coloured water into a glass containing a small portion of *acid,* and the *red* into another containing a small quantity of alkalie, the two colours will be changed, as if by magic, the *green* will instantly become *red*, and the *red green.*

Can you produce a coloured fluid by the mixture of two colourless ones.

Very easily, if I take a weak and colourless solution of nitrate of copper, and pour into it a few drops of *liquid* ammonia, or hartshorn, which is likewise colourless, the mixture will immediately appear of a beautiful blue colour, which colour may afterwards be completely destroyed, and the fluid rendered white again, by only pouring a small quantity of sulphuric acid (oil of vitriol) into it; in this last experiment a curious phenomenon takes place, the sulphuric acid, being heavier than the liquor, sinks to the bottom of the glass, and destroys the colour *there,* while the upper part retains its blue colour; but if the whole is shaken together, *all* the colour disappears.

It was stated that a change of fluids to solids, and of solids to fluids, might be produced by the power of chemical affinity.

This may be shewn by rubbing in a stone mortar nitrate of ammonia and sulphate of soda, or Glauber's salt, both of which will soon lose their solid form, and become perfectly fluid; on the other hand, if a transparent saturated solution of sulphate of magnesia (Epsom salt) be poured into a like solution of caustic potass, the mixture will immediately become almost solid; or if a saturated solution of *carbonate* of potass and one of muriate of lime, be shaken together for one or two seconds, a still more solid substance will be produced.

Are there not instances of solid substances formed by the union of two gases?

Yes, if muriatic acid gas, and ammoniacal gas are mixed, the product will be the solid substance called muriate of ammonia, or sal ammoniac.

This is undoubtedly a most curious experiment, but is there not some difficulty in procuring these gases?

It is true they are both rapidly absorbed by water, and therefore it is impossible to collect them in any considerable quantity, without a trough filled with mercury instead of water; but a quantity of each, sufficient to shew the experiment, may be obtained in a very simple and expeditious way: if you take two dry wide mouthed vials, and rince them out, the one with liquid ammonia, and the other with muriatic acid, on gently heating them, a sufficient quantity of both gases will be raised to fill the bottles, when they may be corked up, and kept for some time, if not immediately wanted; on taking out the corks, and inverting the one over the mouth of the other, dense white clouds will immediately appear, and fall down to the bottom of the vial underneath; this is the salt in question.

It was observed that there were instances of mild substances becoming corrosive, and the contrary, by chemical action.

Instances of this nature are numerous, some of the most remarkable are these; if dried sulphate of iron, or green vitriol (sometimes falsely called *copperas*) be ground in a mortar, with an equal quantity of nitre, and put into a retort, the nitrous acid, or aqua fortis, will, on the application of a lamp, be distilled from it, which is a very *corrosive* fluid, though the two solids which produced it were perfectly *mild;* the formation of the sulphuric and muriatic acids, which will hereafter be described, likewise afford instances of corrosive substances produced from mild ones: on the other hand, if half an ounce of sulphuric acid (oil of vitriol) be poured on an ounce of potass in solution, though the alkalie and acid are both corrosive, yet a mild salt will be the produce of the mixture; or if on one ounce of caustic soda, be poured an ounce of muriatic acid, (spirit of salt) the produce of these very corrosive substances will be muriate of soda, that is the common salt used at our tables.

Has it not been held as an axiom that it is necessary for the chemical action of bodies on each other, that one of them should be in a fluid *state?*

It has, and there is a striking experiment which is usually brought forward in proof of it; if dry powdered nitrate of copper be wrapped up closely in a piece of tin foil, no effect follows, but if it be moistened by a few drops of water, and then folded up, a violent effervescence will take place, sparks of fire will be thrown out, and sometimes the tin foil will be wholly inflamed.

In describing the process used for distilling nitrous acid, the application of heat *was mentioned; in what respects is heat connected with chemical affinity, and in what manner does it promote the composition or decomposition of bodies?*

It must be recollected that the particles of all bodies, when simple or compound, are held together by some bond of union; if a *compound,* by the affinity of its component parts for each other; if a *simple* body, by what is called the attraction of aggregation, which in many cases (as the metals for instance) is exceedingly strong; now caloric, by expanding all bodies, that is, by forcing their particles farther asunder, *weakens* or *destroys* the original compact, and thus prepares the way for new associations; hence, several bodies which have no tendency to combine at a low temperature, will readily combine when heated.

Can you produce an instance of this?

There is a very curious experiment which will prove it; if a piece of iron and a roll of sulphur be brought into contact, they do not, at the common temperature of the atmosphere, discover the least affinity; if the iron be heated to redness, the sulphur will be inflamed, and fall in drops to the ground; but no *union* will take place unless the iron is brought to a *white* heat, *then* if the sulphur is pressed against it, very striking appearances immediately follow, copious and brilliant sparks are thrown off in every direction, the iron dissolves like wax before the fire, and the two substances unite with almost incredible rapidity, forming a new one called sulphuret of iron, a substance which possesses none of the properties of those from which it was formed.

Are there not instances of two substances, which have no natural affinity for each other, being made to combine by means of a third *substance?*

Yes, the manufacture of soap furnishes an instance of this nature, in which water and oil, or water and tallow, are made to combine, through the medium of an alkalie; to form *perfect* soap requires an operation of some length, but the nature of this kind of combination may be easily exemplified; if water and oil be shaken together, they will, as has been observed, separate from each other on being suffered to rest; but if to these, a solution of potass or soda be added, and the whole be now shaken, they will combine, and a fluid soap will be formed: in the manufacture of hard soap tallow is used, and oil in that of soft soap.

Is this the only instance of combinations formed on this principle?

By no means; the dyers are indebted to it in no small degree; they have often occasion to make use of colours that will not *strike*, as the workmen phrase it, that is, there is no *affinity* between the colouring matter, and the material intended to be *coloured*; in this case they employ certain articles, (one of the principal of which is allum) which they call *mordants,* and which have the same properties in dying, as the alkalies in soap-making, they unite the colouring substance with the material to be dyed.

Is not an acquaintance with the laws of chemical affinity of great use in the analysis of mineral waters?

The whole art of analysis, and especially that in question, entirely depends on it.

Is that of mineral waters attended with difficulty?

Not in the present state of chemical knowledge; Chemists being acquainted with all the substances which water is capable of holding in solution, and with the affinities of those substances for others, the analysis becomes easy.

Can you produce some instances, as specimens of these truly curious operations?

Very easily; among the various substances held in solution by water, the sulphuric and muriatic acids frequently occur; the water of the Thames and other rivers, communicating *directly* with the sea, generally, for obvious reasons, contain the latter; now muriatic acid has a strong affinity for silver, if therefore a glass be filled with the water to be tried, and a few drops of nitrate of silver, or a transparent solution of silver in nitrous acid, be put in, the acid will unite with the silver, and form muriate of silver, which, not being soluble in water, will appear in the form of a white cloud, more or less dense, according to the quantity of acid in the water.

By what means can the sulphuric *acid be detected?*

The sulphuric acid having a stronger affinity for the heavy earth called barytes, than for any other known substance, you have only to substitute the nitrate of barytes for nitrate of silver, and, if the water contains sulphuric acid, a white cloud will appear, and fall to the bottom of the glass.

Are not metallic substances sometimes held in solution by water?

Yes, and they may be detected in a similar manner; iron, for instance, is known to have a very strong affinity for the gallic acid, with which it forms ink; if therefore a solution of nut galls in water be put into any water containing iron, the water will become of a *black* colour, more or less strong, according to the quantity of iron in the water, and the strength of the solution employed.

Is this all that is necessary to the making of ink?

No, the iron being so much heavier than the water, would in a very short time sink to the bottom, and leave the water perfectly white and transparent;

to prevent which, the makers of ink employ a quantity of gum to thicken the solution, and thus keep the iron from being precipitated; but this, though it *lessens*, does not *remove* the evil, and the best ink will therefore lose its colour, if it be not *frequently shaken.*

Is the acid *of* galls *the only one for which iron has a strong affinity?*

No, the experiment may be elegantly varied by employing prusiate of potass, instead of a solution of galls, then, if the water contains iron, instead of turning black, as before, it will exhibit the beautiful colour of the *prussian blue.*

By what means may copper *be detected when held in solution by water?*

A very small quantity of this metal is sufficient to tinge a large quantity of water *green,* or to be tasted by the tongue; but if the quantity should be too minute to be thus detected, it may be discovered by dropping some ammonia (spirits of hartshorn) into the suspected fluid, which will, if it contains copper, be turned to a beautiful *blue.*

Are those kinds of inks termed sympathetic *made on this principle?*

They are; for if any thing be written with a solution of sulphate of iron (green vitriol) in water, it will when dried be perfectly invisible; let two papers be written with this, and let one be washed by a feather dipped in a solution of galls, and the writing will immediately become black, let the other be washed with prussiate of potass, and it becomes blue.

Since the knowledge of the affinities of chemical agents is so important, by what means may it be most easily obtained?

There are tables, the result of much and laborious research, called *tables of affinity,* which every student should consult, and which are to be met with in almost every chemical book; by the bare inspection of these, all the affinities of different bodies will be easily understood.

Have not Chemists two different ways of ascertaining the composition of bodies?

Yes; the one is called Analysis the other Synthesis.

What is the meaning of these terms?

By *analysis,* Chemists mean the taking any thing to pieces; and by *synthesis,* the putting it together; thus water is proved to consist of hydrogen and oxygen, because it can be separated into those two component parts, and no more; this is called the analytic proof, or the proof by analysis, and when these two substances are combined, they invariably produce water, and hence arises what is termed the synthetic proof, or proof by synthesis; when both these methods agree, their combined proofs may be considered as decisive.

Recapitulate what has been said on the laws of chemical affinity.

First. It does not exist between *all* bodies. Secondly. It is not always of the same force where it *does* exist, being in some cases very strong, and in others equally weak. Thirdly. It is necessary, in order to the exertion of its influence, that *one* of the bodies should be in a *fluid* state. Fourthly. Its action is influenced by the temperature of the bodies on which it acts; and lastly, bodies which have no natural affinity, may be brought into a state of intimate union, by the interposition of other bodies.

CHAP. VIII.

ON ATMOSPHERIC AIR, AND OTHER GASES.

HAVING examined the simple bodies, and considered the laws of chemical affinity, we may now proceed in the application of those laws to compound bodies; and among these scarcely any can be more interesting than the air we breathe, and which is usually, in philosophical language, termed atmospheric air, *to distinguish it from other airs or gases, is not this a* compound?

It was one of the four elements, or simple bodies, of the ancient chemists, but it is now proved to be a compound, and made up of two airs or gases, *oxygen* and *nitrogen,* with a very small proportion (one hundredth part) of *carbonic acid gas,* which latter however is not essential to its composition but is rather accidentally mixed with it.

In what proportion are the two other gases combined in it?

There are about 77 parts of nitrogen, to 22 of oxygen, in every hundred parts of atmospheric air.

What part does the oxygen gas act in this composition?

It is the oxygen gas as has been stated, which gives to air when breathed, the power of supporting *animal life* as well as *flame,* without its presence animals could not *live,* and a candle would be immediately extinguished; as the remaining part, *viz.* nitrogen will not support either flame or animal life, but is equally fatal to both.

How is this proved?

Very easily; thus, let a glass tumbler be filled with water and then inverted with its mouth under the water, then if any person, by means of a bent tube introduced under it, breathe into the tumbler, the air expelled from the lungs will displace the water, and the tumbler will *appear empty,* though in reality filled with *air* from the lungs; let the mouth of the tumbler be closed while under the water by a saucer, or any other contrivance, and when taken out be placed in its usual position; if the cover be now removed and a lighted wax taper be put in, it will be immediately extinguished.

To ensure the success of this experiment, is it not necessary to keep the air some time in the lungs before it is breathed into the tumbler?

Yes, for otherwise but little of the oxygen which the air contained before breathing, will be absorbed. This is proved by the re-kindling a candle immediately after it has been blown out, as it is the *oxygen* remaining in the air we have breathed which re-kindles the flame. The properties of these airs relative to the support of combustion, may be very prettily illustrated by the following experiments;—provide *three* glasses, let the first remain, as naturally, filled with common air, let the second be filled with nitrogen gas by breathing the air from the lungs as before, let the third glass be filled with oxygen gas. The first glass may be left open at the top, but the two others must be covered till the moment of the experiment, with any thing *flat*, as a piece of glass for instance, to prevent the atmospheric air from mixing with those in the glasses; let a small candle or wax taper be lighted, and burnt till the wick on blowing out the flame remains *red;* if now the lighted taper be plunged into the first glass no effect will be produced, the taper will *burn* as in the open air, plunge the taper into the second and the flame will be immediately *extinguished,* take it out quickly while the wick is red, and on plunging it into the third glass the flame will be re-kindled in the prettiest manner that can be conceived; this experiment may be repeated three or four times without new filling the glasses.

Since the air appears to be indebted to the oxygen it contains for its important property of supporting flame and animal life, would not those purposes be more effectually answered if the nitrogen *were wholly taken away?*

This is only one of numerous instances, in which it may appear to a superficial observer, that the arrangements of the Creator might admit of improvement, but it is not a very easy task to amend his plan; if the nitrogen were taken away and nothing but pure oxygen gas remained in the atmosphere, our candles would indeed burn much brighter than at present, for they would burn with a splendour which the eye could not long endure, they would not enlighten but blind us, and they would hardly be kindled before they would be burnt out; animals too would breathe most delightfully for a short time, but that delicate machine the lungs would presently be worn out, and the now short period of human life be rendered much shorter still.

Nitrogen then answers the purpose of diluting the oxygen, and thereby rendering the atmospheric air more fit for the purposes for which it is intended?

Yes, besides though it seems merely passive in these instances, it performs very important offices in others, it is the basis of a very useful acid, the nitrous, as well as one of the bases of ammonia, and is supposed to be the agent which the Creator employs in "converting vegetables into animal substances."

Was not nitrogen gas formerly called by another name?

Lavoisier who was unacquainted with the fact of nitrogen being the base of the nitrous acid, called it *azot,* and its gas *azotic gas,* from its property, when breathed alone, of depriving animals of life; but this name seems defective in not distinguishing it from other gases, as the carbonic, nitrous, and muriatic acid, which are equally fatal to animal life.

The method of preparing oxygen gas has been already given, is there any method of preparing the other constituent part of atmospheric air, besides that before mentioned?

Yes, if a quantity of sulphur and iron filings are mixed together moistened with water, and then put under a glass vessel full of air, it will in a few days absorb all the oxygen and the remainder will be pure nitrogen gas, or it may be procured more conveniently by pouring very diluted nitrous acid on a piece of muscular flesh and applying a heat of about 100; a great quantity of air is emitted which is nitrogen or azotic gas, and may be received in proper vessels for experiment.

Since a small portion of carbonic acid gas enters into the composition of atmospheric air, this seems to be the proper place for enquiring into its nature —What then are the properties of carbonic acid gas?

Carbonic acid gas was first discovered by the ingenious Dr. Black, to whose patient and accurate investigation of this compound both the English and Foreign chemists are not a little indebted, having found it in a *fixed* state in lime stone, from whence he first obtained it, he gave it the name of *fixed air;* when its great gravity, which is to atmospheric air in the proportion of 1500 to 1000 was afterwards discovered, it obtained the name of *heavy air* its component parts not being then known; it is now proved to be composed, as its name implies, of carbon and oxygen, joined with caloric, it has been ranked by authors, (though incorrectly as we shall hereafter see) among the non supporters of combustion, and it certainly is *not respirable.*

Then the opinion which formerly obtained of the perfect correspondence between the support *of* combustion *and that of* animal life, *is not correct?*

No, for though it is certain that no gas which does not contain oxygen can support either, yet it may happen, that certain substances may have sufficient affinity for oxygen to take it from a gas, when the lungs of an animal cannot, such is the case in the present instance, as the future consideration of the circumstances attending combustion will fully explain.

Is the air or gas which has been so often fatal to dogs and other animals in the famous Grotto del Canna in Italy, of this nature?

Yes, and there is a very curious phenomenon attending that grotto, for a *man* may walk in with *perfect safety,* but if his *dog* should follow him the poor animal would suffer *death.*

To what is this owing?

The superior weight of this gas, as before mentioned, keeps it near the ground, so that unless it is in sufficient quantity to fill the cave, the upper part which is filled with the common air of the atmosphere is harmless, while the lower part where the carbonic acid gas is, proves fatal.

From what materials is this gas extracted?

It is very abundant in nature, it is this gas that is formed by burning *charcoal,* and which has often proved injurious and sometimes fatal to the workmen in different manufactories where charcoal is burned; it is likewise extricated from *fermenting liquors,* hence the accidents that have happened in consequence of persons going down into brewers' *vats* where liquors have been fermenting; and it is this very gas that has so often proved fatal to persons descending into deep pits, or cellars, where a quantity of chalky matter has been deposited.

How is it obtained for experiments?

It is usually obtained from chalk or pounded marble, both of which are carbonates of lime, that is, lime in combination with carbonic acid, by pouring some diluted sulphuric acid on the chalk or marble in a proper vessel, when the carbonic acid gas will be given out abundantly, and may be received over water for experiment.

Can its property of extinguishing flame be easily exemplified?

Very easily, for if a tumbler or any glass vessel be filled with it in the usual way, and a lighted taper be let down into it, the taper will be immediately extinguished; if the vessel be a little agitated, some of the gas will fall over its sides, as water would do, and the taper will *then burn* at the *top* of the vessel, but will be extinguished when it reaches the lower part where the gas is.

Since this gas is so much heavier than common air, would it not be possible to pour it from one vessel to another?

Yes, this is easily done, if it be not done in too much haste, and accordingly if a lighted taper be held in a narrow glass vessel, and another, which contains this gas, be gradually inverted over it, the taper will be extinguished, which shews that the gas has been poured *from* the first vessel *into* that which contained the taper, and to furnish still stronger proof, the taper may now be let down into the vessel which before contained the gas, and it will no longer be extinguished, as before, but will burn as in the open air.

These experiments are certainly highly interesting, and would be more so if it were possible to render the gas visible.

This may be accomplished by throwing a piece of lighted brown paper, or any other smoaking substance, into the gas, which will now attract the smoke, and by that means its height in the vessel, its indulatory motion when the vessel is agitated, its escape over the sides, and falling to the ground, and its pouring from one vessel to another, will be perfectly visible.

Since this gas is so fatal to animals who breathe it, does not this prove it to be of a very poisonous nature?

Not in the least; it is not only *innocent*, but even *salutary*, when taken into the stomach; but if attempted to be breathed, it destroys life, not by any corrosive or poisonous quality, but by preventing the atmospheric air from entering the lungs, in the same manner that water does in drowning, which, nevertheless, has no poisonous quality.

Is there not always some of this gas in the air that is exhaled from the lungs?

Yes, a portion of it is generated in breathing.

Since there is always a portion of carbonic acid gas exhaled from the lungs, and since nitrogen, when separated from the oxygen with which it is combined in atmospheric air, is of a deleterious nature, must it not follow that the air of rooms, or public places, where many persons are assembled, must be very unwholesome?

Not only would *crouded places* be unwholesome, but considerable inconvenience would *in all cases* arise from our being compelled to breathe a second time the air we had already inhaled, but the short space between the expiration and inspiration, affords sufficient time for the nitrogen gas, which is somewhat lighter than common air, to rise above the mouth, while the carbonic acid gas, which is much heavier, sinks below, and thus all ill consequences are by this simple contrivance prevented.

Can any method be taken to prevent the mischiefs which happen to persons going into vats or pits where this gas is found?

Those disasters are easily prevented; we have seen that a candle will not burn in this gas, we have therefore only to let down a candle to the *bottom* of the pit or vat; if it *burns,* all is safe, if the contrary, the *extinction* of the candle proves that there is some of this gas present, you have only to throw in a quantity of *quick* lime, sprinkled with water, this will soon absorb the carbonic acid, for which it has a very powerful affinity, and on letting down a candle again, its burning will prove that the descent may *now* be made with *safety;* in the mean time, as the gas always keeps at the bottom, there is no danger to be apprehended from a person looking into the pit; you may even ascertain, by letting down the candle *slowly,* how high the gas reaches.

The gases which compose our atmospheric air, together with the oxygen, hydrogen, nitrogen, carbonic acid, and ammoniacal gases, having been described, are there any others whose peculiar properties render them deserving of particular attention?

Yes, there are several, among which may be reckoned the fluoric acid gas, which possesses the very singular property of dissolving silex, the earth of which glass is made, and of corroding glass itself; but this will more properly be considered when we come to speak of the acids.

In describing the properties of oxygen gas, you observed that its effects in breathing were of an exhilarating *nature, is there not another kind of gas which possesses the same property?*

Yes, and in a much greater degree, from whence it has been called *exhilarating gas,* but its proper name is gaseous oxyd of nitrogen, or nitrous oxyd; it is said to occasion a rapid flow of delightful ideas, as well as an irresistible propensity to laughter; and it often occasions such a degree of muscular exertion in attempting to leap, &c. that it is very difficult to hold the person who has inhaled a sufficient quantity of it; its effects, however, are very different on different *subjects,* on some persons it has no visible effect, while others are affected to such an astonishing degree, as to occasion no small alarm in the minds of those who have never before witnessed its effects.

In what manner is it prepared?

It is distilled from nitrate of ammonia, which is prepared by saturating nitrous acid with carbonate of ammonia; when this is put into a glass retort, and the heat of a lamp applied, the gas comes over very plentifully, and is to be collected as usual over water; when it is used, a bladder, with a pipe for the mouth, is to be filled with it, the person who is to breathe it must previously empty his lungs, as far as possible, of air, and holding his nostrils, inhale the gas from the bladder until it begins to take *effect,* after which no direction is wanting, as the person generally receives it with great avidity, and will not suffer the bladder to be taken from his mouth, until the operation of the gas begins to decrease: it is worthy of remark, that those who have once breathed it, are generally exceedingly desirous of repeating the experiment.

Does it appear that any ill consequences have ever arisen from it?

No, on the contrary, those who have been most powerfully affected, when the effects have subsided, (as they gradually do after two or three minutes,) have declared that it leaves a pleasing kind of disposition to action, which is not followed by any langour or debility.

Was not Mr. Davy the first person who ventured to breathe it?

Yes, and he has since been in the habit of inhaling it very frequently, without the least ill effect.

Is there not a gas *in which combustibles take fire spontaneously?*

Yes; it is *properly* called *hyper oxygenized* muriatic acid gas, but the frightful length of this name has occasioned its reduction to *oxy muriatic;* it is usually prepared by distillation from eight ounces of muriatic acid, and four of manganese, or eight ounces of common salt, three of manganese, and four of vitriolic acid, diluted with an equal quantity of water, using a glass retort, and when the gas slackens applying the heat of a lamp; it may be collected over water like the other gases, but as it is of a very suffocating nature, care must be taken that little or none of it escapes, so as to be taken into the *lungs*.

If, notwithstanding all possible care, some of the gas should escape, what is to be done to prevent its bad effects?

This is certainly liable to happen; in this case the operator must use all practicable precaution, such as keeping as far as possible from the apparatus, or holding his breath when he approaches it; but when it is known to have escaped into the air of the room, its deleterious effects may be prevented, and itself indeed *neutrallized*, by letting some ammoniacal gas into the room, or even by sprinkling some liquid ammonia in the air.

Describe the properties of this gas.

Its effects in bleaching are very powerful, as may be shewn by exposing *coloured* linen to its action, for if a piece of almost any *coloured* linen be put into a jar of this gas, the colour will in a very short time disappear, and the linen be rendered perfectly *white*; ink spots, and the stains of fruit, red wine, &c. may in like manner be discharged by it.

How may the power of this gas in producing spontaneous combustion *be shewn?*

You have only to throw the combustible into a jar filled with this gas, and it will *immediately* take *fire,* without previously heating; if a leaf of dutch gold be thrown into it, it burns in an instant, or if powdered *antimony* is sprinkled into it, it exhibits the beautiful appearance of a *shower* of *fire;* other metals may be burnt in it, but it is necessary they should be in thin leaves, or else in powder or filings.

CHAP. IX.

ON WATER.

IN the enumeration of simple bodies *it was observed, that* water, *though by the ancient Chemists considered as simple, was now proved to be* compound—*What then are the materials that enter into its composition?*

Water is composed of *oxygen* and *hydrogen,* in the proportion of 85 parts of the former to 15 of the latter in every 100 parts of water.

By what means is the composition of water ascertained?

Both by analysis and synthesis; it was stated, in describing the means by which hydrogen gas is formed, that if iron or zinc filings be put into diluted sulphuric acid, *hydrogen* gas will be set at liberty; there is here a real *decomposition* of the *water;* its oyxgen combines with the metal, while the hydrogen is consequently liberated, and united to caloric, in the form of gas; if this experiment is made in a vial, and a cork with a piece of tobacco-pipe is fitted *air tight* into it, the gas, as it issues from the vial, may be set on fire, and will continue to burn as long as any gas rises; this has been called the *philosophical candle.*

Cannot water be decomposed, so as to shew its composition, without the use of sulphuric acid?

Yes, if it be made to pass, in the state of vapour or steam, through a *red hot* tube in which some *iron* filings are placed; the iron, as in the last experiment, will seize the oxygen, the hydrogen gas will come over, and may be burned as in other cases. Lavoisier was one of the first who ascertained the composition of water by a process similar to this, but instead of iron filings, he used charcoal, the consequence was that though the water was decomposed, by the charcoal taking away its oxygen, yet the gas given out was not *hydrogen*, but *carbonic acid* gas, being composed of oxygen and carbon.

These experiments certainly prove that hydrogen is one of the component parts of water, but as for the existence of oxygen, especially in so large a proportion as that which has been stated, does it not seem to be rather in these cases taken for granted, than fairly proved?

By no means, for if the metal be examined after the experiment, it will be found that its weight is increased, its surface corroded, and no longer metallic; it is in fact an *oxyd*, and if a sufficient quantity could be collected, put into a retort, and exposed to a red heat, *oxygen gas* might be obtained from it, as it now usually is from the rust or oxyd of manganese; but as oxygen when *solid* occupies so much smaller space, than when combined with hydrogen in a *fluid* state, it cannot be expected that any *considerable* *quantity* should be found in combination with the metal.

How is the composition of water proved by synthesis?

If the two gases are mixed together in the proportion before stated, and an electric spark passed through them, they will entirely disappear, and nothing but a small quantity of water will remain in the vessel.

As this experiment must necessarily require some nicety, and a complicated apparatus, cannot the fact be proved in an easier way?

Yes, if any glass vessel be held over the flame of hydrogen gas, the hydrogen will combine, as in all the usual cases of combustion, with the oxygen of the atmosphere, and *water* will be *formed,* which will appear on, and trickle down, the sides of the vessel. If a glass tube of not less than an inch diameter, and about two foot long, be used, there will not only be water formed on its sides, but a very singular sound will accompany the phenomena, somewhat resembling (though less soft) that produced by the œolian harp.

Has hydrogen any other remarkable properties besides that of forming water by its union with oxygen?

Yes, in the state of gas it has the property, as before observed, of dissolving and holding in solution several substances, as sulphur, charcoal, phosphorus, with which it forms sulphurated, carbonated, and phosphorated hydrogen gas, the latter of which is so exceedingly inflammable, that it takes fire the instant it comes into contact with the air.

Its formation then must furnish a very curious experiment, how is it produced?

By putting a piece of phosphorus into a small retort, nearly filled with a strong solution of pure caustic potass, and immersing the beak of the retort under water; if the heat of a lamp be now applied, and the solution be made to boil, bubbles of phosphorated hydrogen gas will be evolved, which will take fire the instant they reach the surface of the water, and, if the air of the room be tolerably still, curious coronets of smoke will be formed by the bursting of the bubbles.

What is the comparative gravity of hydrogen gas?

It is about thirteen times lighter than common air.

How can this be proved?

To ascertain *precisely* the gravity of this or any other gas, requires much attention, and a very delicate apparatus; but that hydrogen is *considerably* lighter than common air may be very easily proved in several ways; for instance, if to a bladder containing some hydrogen gas, a common tobacco-pipe be attached, and soap bubbles be blown, they will, when detached from the pipe, be seen to rise rapidly in the air, and break against the ceiling of the room; if a candle be held to them while rising, they will take fire and burst; it is on account of the *lightness* of this gas, that it has been employed for the purpose of filling air balloons.

When it is fired, is its inflammation attended with explosion?

Not unless it be mixed with oxygen, or any gas containing oxygen, (as atmospheric air); but if bubbles be blown, by means of a bladder containing a mixture of the two gases, in the proportion of about one part of oxygen to two of hydrogen, they will, on setting fire to them, explode; if a number of bubbles are formed *together*, by immersing the pipe in soap-suds in a bason, the report will be very loud.

In stating the proportions of oxygen and hydrogen in water, it was said that 85 *parts of the former were combined with* 15 *only of the latter, how is it then that in mixing the two gases, the proprotions are reversed, and oxygen, instead of being in the large proportion of near six to one, is reduced to only one half the quantity of the hydrogen?*

The proportions of the two substances in *water* were stated by weight, but when speaking of the mixture of the two bodies in the state of *gas*, the *bulk* only was regarded; the volume or bulk of a gas depends, not on the quantity of the original matter which it contains, but on the quantity of caloric combined with it; caloric is an imponderable substance, and consequently the more of this any other substance requires to bring it to a gaseous state, the lighter will the gas be; oxygen gas is rather heavier than atmospheric air, but hydrogen gas, it will be recollected, is twelve or thirteen times lighter.

Are oxygen and hydrogen capable of uniting, as is the case in other instances, in different proportions?

No, for though oxygen will unite with nitrogen and several other bodies in different proportions, yet with *hydrogen* it will combine only in *one* and water is always the product of their union.

In speaking of oxygen, it was stated to be the general principle of acidity; *now as acids owe their corrosive nature to the oxygen they contain, does it not seem to follow that water, which contains so large a portion of oxygen, even greater than that of* nitrous acid, *should be a very* corrosive *fluid, instead of a mild and* tasteless *one?*

It must be recollected that, as in the case of *heat*, bodies *appear hot*, and actually heat *us*, not in proportion to the caloric they *contain*, but in proportion to that which they *impart;* so the *acids* are *corrosive*, not because they *contain*, but because they *give out*, oxygen; water would indeed be a most dreadful poison, instead of a salutary beverage, had not the Almighty bound its ingredients together by a force not easily broken; the affinity of oxygen for hydrogen, with which it is combined in water, is much greater than its affinity for nitrogen, which it is united to in nitrous acid; and hence it is that the former is *not* corrosive, though containing so large a portion of oxygen, while the latter, though containing less, is most dreadfully so.

It was stated, when speaking of the properties of caloric, that its most general effect is the expansion of all bodies into which it enters—Is not water very much expanded when raised into steam?

Yes, it occupies no less than 1200 times the space which it filled when in its fluid state, or below the temperature of 212 degrees.

Is not water, at a certain temperature, an exception to the general rule?

Yes, water furnishes a very remarkable, and very merciful exception, for though above 42½ degrees, it obeys the *general* law, yet, when cooled below that standard, it obeys no longer, but expands as it cools, and in the solid state of ice, actually occupies a larger space than when it was fluid.

This is indeed a wonderful circumstance, but how is it proved?

By the swimming of ice on water, which could not happen, unless its specific gravity were lessened, or, which is the same thing, its *bulk* increased.

What would have been the consequence of subjecting water, at all temperatures, to the general law?

The consequence would have been, that when the surface of the water was become ice, instead of presenting, as it now does, a kind of barrier between the cold air and the water underneath, it would have sunk to the bottom, and thus by exposing continually *fresh surfaces* to the action of the cold air, our rivers would soon have become totally solid, our fish must have died, and a very considerable time must have elapsed before the waters so frozen could have been thawed; perhaps the whole heat of our summers would not have been sufficient to have effected it—What an admirable contrivance of divine Providence is this exception from an otherwise general law of nature.

Have not some interesting experiments been made on this singular property in water?

Yes, *iron* shells and *cannon* have been filled with water and closed up, and afterwards exposed to a degree of cold sufficient to freeze the water, and so astonishing has the force been found, with which it expands in the act of freezing, that it has invariably burst its strong inclosures, nor does it appear that any force is capable of confining it.

CHAP. X.

ON ACIDS.

WHAT are the characteristics of an Acid?

The first property by which acids are distinguished from other bodies, namely, their *sour* taste, is universally known; their second property is the changing vegetable blue colours to *red;* it has been already stated, that the *alkalies* also are known by their effects on vegetable colours, but the same blue which an alkalie would turn to *green,* is by an acid changed to *red,* and thus the presence of either of these bodies in any solution may be easily detected; the common purple paper, such as sugar loaves are wrapped in, will answer very well for common purposes, it turns red with most of the acids, and though the alkalies do not change it to *green,* yet they destroy the red colour given by the acid, and restore the purple colour; but one of the best tests, because the most delicate, is obtained by pouring boiling water on red cabbage, this, as we have seen, when considering the effects of chemical affinity, will be turned by an alkalie into a beautiful green, while an acid will change it to a lively red.

Is there not another property by which acids are known?

From what has been already said on the properties of an alkalie, it will be inferred that a third property of the *acids* is their *effervescing* with *alkaline* substances, for whenever an alkalie is put into an acid solution, a visible commotion ensues, a hissing noise is heard, and numerous bubbles rise to the surface of the fluid, and when all is quiet, if the alkalie and acid have been properly *proportioned*, it will be found that the two opposite substances have neutrallized each other, and the solution is neither alkaline or acid; this fact may be easily exemplified by tinging some water (not less than three or four ounces) with any of the vegetable *blues* before mentioned, add some solution of potass, and it will be green, indicating the presence of an alkalie, but by cautiously dropping in any diluted acid, the green colour may be made to disappear, and the original colour be restored, because the alkalie in the solution is saturated by the acid, that is to say, its alkaline property is destroyed, and it therefore no longer effects the colour: the counter part of this experiment may be shewn by first tinging the solution *red* by an acid, and then destroying that red, and restoring the original blue by dropping in by slow degrees a weak solution of an alkalie; thus proving that the alkalies and acids mutually act on, and destroy each other: such are the marks laid down for ascertaining when any substance is of an acid nature, or contains any acid, but it must be observed, that all the bodies of this class do not possess *all* these qualities in an equal degree, and in some cases there is a deficiency of at least one of them.

It was stated that one of the properties of an acid is to change the vegetable *blues to red, then it is* only *the blue colours which are produced from* vegetables *that are* so *changed—can you exemplify this by experiment?*

Yes, if some tincture of litmus, or infusion of red cabbage, be put into one glass, and some of the blue liquor produced, as before mentioned, by dropping ammonia into a solution of nitrate of copper, be put into the other, very different effects will follow on dropping a little muriatic or any acid into each, for the vegetable colour will be turned *red*, but the metallic one will be totally *destroyed.*

How many acids are there?

The acids, at present known, amount to about *thirty*, but when it is considered, that though there is but one *acidifying principle*, yet that one is capable of combining with a variety of substances, both simple and compound, so as to form a substance which may exhibit at least some acid properties, it is therefore impossible to say to what extent the list of acids may hereafter be carried: perplexed, however, as this branch of chemistry may at first sight appear, there is at least this consolation, that if an acquaintance with *all* the acids is a matter of some difficulty, it is happily, to the young Chemist, a matter of no great importance; it is in fact with the acids, as with the metals and earths, some of them are mere play-things, and others are only used as tests, or re-agents, as they are called, to determine the nature of other substances, and that perhaps only in a single instance.

What then are the principal *acids?*

The principal acids are the Sulphuric, Nitric, Muriatic, Acetous, Carbonic, Fluoric, Prussic, and Phosphoric.

How is the Sulphuric *acid made?*

It was formerly distilled from sulphate of iron, which being called *green vitriol*, and the acid drawn from it being a very heavy fluid, was absurdly called *oil* of *vitriol;* the manufactories where sulphuric acid is made, are still called *vitriol works;* but it is now made by burning sulphur in a leaden chamber, in which water is contained, the acid vapour as it arises is absorbed by, and condensed in, the water, which is rendered acid by it, and being afterwards concentrated by boiling, forms sulphuric acid; a certain quantity of nitre, in the first instance, is added to the sulphur, for the purpose of furnishing more oxygen than the air of the chamber would yield.

What are the principal properties of this acid?

It is naturally *colourless*, but if any carbonacious, or combustible, matter, as a cork, or piece of wood or paper, comes into contact with it, it becomes *dark* coloured, though without injury to its properties; it has no smell, but is highly *corrosive;* if a drop of it, especially when diluted, fall on linen or woollen cloths, it almost immediately makes a hole; it has the striking property of elevating the temperature of water very considerably, when *suddenly* mixed with it; four parts (by weight) of this acid, mixed with one of water, will produce a heat equal to 300 degrees, which is 88 above *boiling* water, and if a *thin* glass tube containing water be immersed in it, the water will be seen to boil.

What are its principal combinations?

It acts very powerfully on some of the metals; with iron, which in a diluted state it rapidly dissolves, it forms the green salt vulgarly called *copperas,* but properly sulphate of iron; it acts likewise as powerfully on zinc, and with it forms sulphate of zinc, which has been, ridiculously enough, called *white copperas;* in common with the other acids, it unites with the alkalies and alkaline substances, forming, according to the substances it unites with, sulphate of *soda,* or Glauber's salt, sulphate of *lime,* or plaster of Paris, sulphate of *magnesia,* or Epsom salts, &c.

Does sulphur combine with oxygen in different proportions?

Yes, with a less proportion of oxygen than is required for the formation of sulphur*ic*, it forms what, in the new nomenclature, is termed sulphur*ous* acid.

Do the two acids differ in any other respects than the degrees of strength or acidity?

Yes, contrary to what would have been supposed, their *properties* are *different;* sulphuric acid has no smell, sulphur*ous* has a very suffocating one; sulphur*ic* acid changes the vegetable blues to *red,* but the sulphur*ous destroys* this and every other colour, and leaves the coloured substance *white*; hence, says Mr. Parkes, if a *red rose* be held in the fumes of a brimstone match, the colour will soon begin to change, and at length the flower will become perfectly *white.*

Might not this property of the sulphurous *acid be applied to the removal of ink and other stains from linen?*

Yes, if the stained part be first moistened with water, and then held over the fumes, the stain will generally disappear, and on this principle it has been used for the purpose of whitening silk; this bleaching property appears to have been known as early as the days of Pliny the Naturalist, who mentions its use in whitening wool.

How is the Nitric *acid made?*

It is distilled from nitrate of potass (salt petre); a quantity of this is put into a retort, and sulphuric acid poured on it; on the application of heat the sulphuric acid combines with the potass, forming sulphate of potass, and the nitric acid being set at liberty, is distilled over in yellow vapours, which condense in the receiver

What are the properties of this acid?

Pure nitric acid is colourless, but it generally appears of a *yellow* colour, owing to the presence of nitrous gas, though the colour varies according to circumstances to a green, or even blue; it is the most *corrosive* of all the acids, has a very pungent smell, and if dropped on the skin it stains it of a bright yellow, which is not to be removed until it gradually *wears* away, or a new skin is produced; it is formed of the very *same materials* as atmospheric *air*, but in different proportions, the acid containing 75 parts of oxygen, to about 25 of nitrogen, whereas atmospheric air contains only 22 parts of oxygen, to 77 of nitrogen.

Does it not act on the metals?

Yes, it acts very powerfully on most of them, emitting during its action copious *red fumes;* with copper it forms *nitrate* of *copper*, the curious property of which has been already mentioned; with silver the lunar caustic, used by the surgeons to destroy proud flesh, &c. it has no action, however, on gold or platina, unless it be mixed with one half its weight of muriatic acid, when it forms what is called *aqua regia*, and is rendered capable of dissolving those metals.

Is Nitrogen capable of combining with oxygen in more than one proportion?

Yes, and with a portion somewhat less than that which constitutes nitr*ic* acid, it forms nitr*ous* acid, the properties of which so nearly resemble those of the nitric, that a particular account of them is unnecessary.

What is the nature of the Muriatic *acid?*

This acid never having been decomposed, its *base* is consequently *unknown;* it is obtained from muriate of soda (common salt) from whence it takes its name; the process for obtaining it is exactly similar to that for preparing nitric acid, but substituting the muriate of soda for the nitrate of potass; it rises in the form of *gas,* but is condensed by water in the receiver, and forms with it the liquid muriatic acid, or *spirit* of *salt;* if therefore the *gas* is intended to be preserved for experiment, it must be received over *mercury,* and preserved in vessels perfectly free from moisture.

Does hot or cold water absorb it equally?

No; in proportion as the water is *heated* it absorbs *less* of the gas, and at a *boiling* heat it does not absorb *any,* and consequently when the liquid acid is heated, it parts with the gas, and is reduced to water; it was in this way that Dr. Priestley first obtained it; this gas possesses the property of neutrallizing putrid effluvia, and thus preventing their pernicious effects; it is said that the French Chemist Morveau, after several means had been tried without effect, succeeded in purifying, by means of this gas, the Cathedral of Dijon from putrid exhalations, that had prevailed to such a degree, as to occasion the entire desertion of the place.

Is oxygen capable of combining with the base of the muriatic acid in different proportions, so as to form distinct acids?

Yes, the acid called oxy-muriatic, already noticed, *contains a greater* proportion of oxygen than the muriatic, though it can perhaps hardly be said to be *combined* with, but is rather *forced* into it, in consequence of which it parts with its additional quantity of oxygen to almost any body that is presented to it, even *light* is sufficient to decompose it; it is remarkable that the acid properties of this compound are not increased by the *additional* oxygen it contains, on the contrary, its *very acid taste* is completely *gone*; it no longer *corrodes* even the finest linen; instead of rendering vegetable colours *red,* it now totally *destroys* them, hence its use in bleaching, for which purpose it may be used either in the state of a gas, or that of a liquid.

The method of preparing the gas *having been already described in speaking of the different gases, Is it sufficient, for the purpose of forming the* liquid acid, *that the receiver, as in other cases,* contains *water?*

No, in this instance also there is a considerable difference between the common muriatic, and the *oxy*-muriatic acid gases; the former is so rapidly absorbed by water, that it cannot be collected unless over mercury; but, on the contrary, the latter is so sparingly absorbed, that it is not sufficient that the receiver *contains* water, but the gas must be made to pass *through* the water; a considerable degree of *pressure* must be used, and the fluid *agitated* as much as possible, which requires a peculiar kind of apparatus, called Woulfe's bottles, to be added to the first receiver.

Is this liquid the same with those called bleaching *liquids?*

Not exactly; the best liquid for this purpose is made by passing the gas through *lime* water, instead of common water; if a written paper be *dipped* in this, or if the liquid be washed over it with a feather or camel hair pencil, the writing will very soon totally disappear, as will fruit stains, &c. from linen.

Might not this property of the oxy-muriatic acid be used, for the purpose of defacing the writing of legal instruments, for bad purposes?

Undoubtedly, but chemistry, while it furnishes the means of fraud, furnishes also the means of prevention, and detection; for if some of the black oxyd of *manganese*, and *indigo*, be added to the common ink, it cannot be taken out by the application of acids; and if any writing *has been* taken out, it may be restored again, or at least rendered *legible*, by the application of sulphuret of ammonia, and prussiate of potass.

What is the nature of the Acetous *acid?*

Acetous acid, or vinegar, was probably the first acid known; as all fermented liquors are liable to turn *sour,* if not kept from the action of the air, from whence they derive that portion of oxygen which converts them into vinegar, it must consequently have been known nearly as early as the production of *wine,* that is as soon as the time of Noah; the nature and properties of this acid are familiar to every one; its uses in forming white lead, acetite of lead, verdigris, &c. have been already noticed, the common vinegar, however, is not pure, being mixed with several substances, but it is easily purified by distillation, when it becomes colourless; the acet*ic* acid, though radically the same with the acet*ous,* yet possesses some different properties, so as to be considered as a distinct acid; it is distilled from verdigris, and is considerably more pungent than the acetous.

What is the nature of the Carbonic *acid?*

Carbonic acid is known to be a compound of carbon and oxygen, and may therefore be formed by the combustion of *charcoal,* but it exists ready formed in *chalk, marble,* &c. and in a solid state; the usual method of obtaining it, and its several properties, have been considered when speaking of the gases, it only remains to observe, that though it is not condensed by water, as other gases are, yet water may be made, by pressure and agitation, to absorb a portion of it; *glass* machines, called *Nooth's* machines, have been constructed for this purpose; the water thus impregnated has a brisk and slightly acidulous taste, resembling the Seltzer water; it is to small bubbles of this gas that Champaign and some other liquors owe their sparkling appearance.

How is the Fluoric *acid prepared?*

The sulphuric acid, of so much importance in the formation of other acids and their gases, performs an important part in the production of this, which is obtained by pouring sulphuric acid on some pounded fluate of lime, usually called *Derbyshire spar,* the sulphuric acid seizes the lime, and forms with it sulphate of lime, or plaster of Paris, the fluoric acid is disengaged, and rises in the form of gas, which is, however, easily absorbed by the water in the receiver, with which it forms liquid fluoric acid.

If this acid is capable of corroding glass, as formerly stated, then it cannot be either prepared or kept, as the other acids usually are, in glass *vessels?*

No, and therefore *leaden* ones, which it does not act on, are used, both to *prepare* it, and to *keep* it when prepared.

Might not this property be applied to the purpose of etching on glass?

It may be used for etching on glass in the same manner as nitrous acid, or aqua fortis, is for etching on copper; for if a plate of glass be first covered over with melting wax, and the design afterwards traced with any pointed instrument, if it be afterwards exposed to the action of the gas, or if the liquid acid is poured on the plate (which should be edged with wax, to keep it from running off,) the whole design will be very legible when the wax is cleared away; in this way plates of glass *have* been etched, and impressions taken off, but the difficulty of submitting the glass to the great degree of pressure, which is necessary in taking off an impression, would alone be an insurmountable objection to its general use.

Are the effects of the liquid acid, and those of the gas precisely the same?

No, the lines formed by the liquid are *bright*, like the other parts of the glass, but those formed by the action of the gas are *opake*.

How was the singular property of this acid first discovered?

By accident, as many other discoveries of far greater importance have been made: Henry Swanhard, of Nuremberg, first discovered it in the year 1670, in consequence of having spilt some of the acid on his spectacles, the glasses of which he found were corroded by it.

What is the nature of Prussic *acid?*

The Prussic acid is the colouring matter of the beautiful and well known *prussian blue*; it is obtained by exposing bullock's blood, or the horns, &c. of animals, to a red heat, with potass, by which a prussiate of potass is formed, which has the property of producing a blue precipitate from a solution of iron, which is the prussian blue; this acid has the property of precipitating metals from any solution, by forming an insoluble compound with their oxyds; the colour of the precipitate ascertains the nature of the metal, thus the precipitate of iron, as observed, is *blue*, that of gold *yellow*, that of lead *white*, and that of copper *brownish red*—a property which renders it highly important to the Chemist.

What is the nature of Phosphoric *acid?*

Phosphoric acid is composed of phosphorus and oxygen; if phosphorus is burnt in oxygen gas, a dense white cloud appears in the vessel, which adheres in the form of flakes to its sides, this is the acid, and the whole process of making phosphorus, though attended with considerable difficulty, consists, in reality, in separating it from the oxygen again; it is this acid combined with lime, forming a *phosphate* of *lime*, which is the basis of animal bones; by the slow combustion of phosphorus in common air, an acid is obtained, called phosphor*ous* acid, in distinction from the phosphor*ic*.

What are the names of the other acids?

The *Oxalic*, which is extracted from sugar, and exists ready formed in the wood sorrel, has the useful property of precipitating lime from its solutions; the *Gallic* is found in nut galls, which precipitates iron *black*, and is therefore useful in forming inks; the *Citric* obtained from lemons and oranges, the *Camphoric* from camphor, the *Lactic* from milk, the *Sebacic* from fat, the *Suberic* from cork, the *Succinic* from amber, together with several others, the properties of which are either so uninteresting, or so little known, that the attention of a young Chemist would not be very profitably employed in their examination.

CHAP. XI.

ON SALTS.

IT has been noticed, in speaking of the acids, *that in combining with certain substances they form new ones, which are termed* Salts—*What is the nature of these combinations?*

The word Salt is in common acceptation confined to a very few bodies, principally to muriate of soda; in medicine it is extended to others, as the sulphates of magnesia and soda; but among Chemists it has a more extensive signification, and is applied to all the combinations of the *acids* with the metallic *oxyds, alkalies,* and *earths;* their principal characteristic property is their solubility in water, and their insolubility in alkohol, or spirit of wine; hence, if alkohol be added to a watery solution of any salt, the salt is precipitated from its solution; these combinations are of course very numerous, amounting to about 1800, among which it will naturally be expected that some are of much higher importance than others.

If so great is the number of salts, is it not difficult to name them, so as to avoid confusion?

Formerly the difficulty would have been insuperable, and every fresh discovered substance would have increased the embarrassment of the chemical pupil; this difficulty is now not merely *lessened,* but *totally removed,* by the introduction of that admirable nomenclature which the great Lavoisier, and the "illustrious body of French Chemists" associated with him, have introduced; the mere consideration of the unavoidable confusion occasioned by the old names, must convince every one of the necessity of a reform in this branch of Chemistry, and of the service which those Chemists have rendered to the science, and to the world, by effecting it.

What are the advantages of this nomenclature?

Previous to its introduction, every newly discovered substance was named at random; sometimes from its discoverer, as *Glauber's* salt, sometimes from the place where it was found, as *Epsom* salt, sometimes merely from its colour, or other fanciful resemblance, as *liver* of sulphur, names which have no connexion whatever with the *nature* of the compound they are meant to designate; but there are names still more exceptionable, such as *oil* of *vitriol;* vitriol itself is a vague term, and belongs no more to sulphate of iron, than it does to almost all salts, and the substance in question is certainly *not* an *oil.*

How does the new nomenclature prevent this confusion and error?

By giving to the *compound* a name formed from the names of the substances which *compose* it; thus, instead of *Glauber's* salt, we say *sulphate* of *soda,* that salt being formed of sulphuric acid and soda; *Epsom* salt, being a combination of the same acid with magnesia, is called *sulphate* of *magnesia;* and the absurd and false appellation of *oil* of *vitriol* gives way to the rational name of sulphuric acid, that acid being formed, not by the mixture of oil and glass, as the old name would seem to imply, but of sulphur combined with oxygen. Let us imagine that our common table salt were shewn to a Chemist who was ignorant of its nature, and who would naturally be disposed to enquire whether it were a simple substance or a compound, and if a compound, of what materials it was formed? such is the admirable plan of the present nomenclature, that no sooner is the proper name of this salt, *muriate* of *soda,* announced, than all questions relative to its nature are answered, or rather the necessity of asking them is superseded.

Since the whole number of salts cannot at present be examined—What are those which, on account of their properties, or the uses to which they are applied, are most worthy of observation?

The principal of these are formed by the combinations of those acids, the properties of which have been already described, and several of the salts themselves have been unavoidably noticed, in speaking of the acids and metals; the salts formed by union of the sulphuric acid with oxyds, earths, or alkalies, are, agreeably to the present nomenclature, termed *sulphates;* those of the metallic oxyds have been already mentioned in our consideration of the metals themselves; with the alkalies it forms sulphate of soda, or sal mirabile, or Glauber's salt, sulphate of potass, or vitriolated tartar, which with sulphur forms the sal polychrest, &c. with the earths it forms sulphate of barytes, or ponderous spar—sulphate of magnesia, or Epsom salt—sulphate of lime, or plaster of Paris—sulphate of alumine, or allum, &c.

In stating the application of the nomenclature to acids, *it was observed that those acids which contained the largest portion of oxygen were distinguished from those which contained less, by the termination of their names, the former ending in* ic, *and the latter in* ous—*Is there any distinction in the names of the salts formed from the different acids?*

Yes, the salts formed by the acids whose names terminate in *ic*, are distinguished by the termination *ate;* thus the salts formed by the nitric acid are called nitr*ates*, while those formed by the nitr*ous* acid end in *ite*, and are called nitr*ites*; and thus we have the sulph*ate* and the sulph*ite* of barytes, and so of all the other salts.

What are the principal salts formed by the Nitric acid?

Besides the metallic salts, which have been already named, it forms, by its re-union with potass, the well known salt called nitre, or salt petre, of so much importance in several of the arts and in the manufacture of gunpowder—that terrible compound consisting of 75 parts of nitrate of potass, to 16 of charcoal, and 9 or 10 of sulphur; these are ground and mixed together while *wet*, and afterwards reduced to grains by passing through a seive, and finished by drying; from the quantity of oxygen which nitre contains, and the facility with which it parts with it, it forms the principal part not only of gunpowder, but of most of the detonating compounds; when three parts of nitre, two of potass, and one of sulphur, are well dried, and mixed together while warm, they form what is called *fulminating* powder; if a little of this is held in a spoon over the candle, or in a shovel over the fire, it soon begins to melt, when it *explodes* very loudly, though not attended with the smallest *danger;* the nitric acid combines likewise with soda, and the earths, and forms with them a variety of salts, not at present particularly interesting.

What are the characteristics of the salts formed by the combination of the Muriatic acid with the alkalies and earths?

There is one property in the *muriates,* as they are called, worthy of observation, namely, that though they are the most volatile, yet they are not like other salts to be decomposed by fire: Mr. Parkes once kept some muriate of soda in the most intense heat of a reverbatory furnace for 48 hours, without its being in the least degree altered.

What are the principal Muriates?

Besides those already described, there are the muriate of ammonia, or sal ammoniac, the muriate of potass, or febrifuge salt, the muriate of lime, used for bleaching, and others of less note; but the most remarkable salt belonging to this class is the oxy-muriate of potass—if the oxy-muriatic acid gas, before described, be passed through a solution of potass, instead of water, until the solution is saturated, small crystals will fall down, which is the salt in question, and is one of the greatest curiosities which the art of Chemistry has produced; it seems, says *Fourcroy*, "to include the elements of thunder in its particles—a Chemist can produce effects almost miraculous by its means, and nature seems to have concentrated all her power of detonation, fulmination, and inflammation, in this terrible compound:" If three parts of this salt be powdered, and mixed with one part of flowers of sulphur, and then laid on an anvil, or any solid body, and smartly struck with a hammer, it detonates violently; the mixture will even explode spontaneously if kept in a warm place; if ten grains of this salt be put into a mortar with one of phosphorus, and then rubbed together, successive and violent detonations will be produced; in performing this experiment, it is advisable to turn the mouth of the mortar from the face, as small pieces of phosphorus sometimes fly out.

May not some substances be inflamed without detonation by means of this salt?

Yes, if equal parts of lump sugar and oxy-muriate be first *pounded,* and then *mixed* together, a single drop of sulphuric acid will be sufficient to *inflame* the mixture, from which a beautiful column of flame will rise; it was proposed by *Bertholet,* who first discovered this salt, to use it instead of nitre in the manufacture of gunpowder, but the attempt having caused the death of two of the workmen employed, it was laid aside, though it is said that the French have since used it; a patent has lately been taken out for a peculiar kind of gun lock, in which this salt is to be used, but it is to be hoped it will never come into general use.

CHAP. XII.

ON COMBUSTION.

THE appearances accompanying the combustion of inflammable bodies, and the effects produced by it, are of a very interesting nature—have they any relation to Chemistry and its laws?

The process of combustion is altogether of a chemical nature, and is in reality only what is termed by Chemists a play of affinities.

What! is Combustion, *by which such ravages have been made—by which* houses, ships, *nay, whole* towns *and* fleets, *have been* destroyed, *and by which such extensive calamities have been occasioned; is all this regarded by Chemists as a mere* play *of* affinities?

It really is so, and nothing more, nor is there in all these calamitous circumstances, how extensive soever they may have been, a single particle of matter *destroyed;* by combustion indeed the *forms* and *properties* of bodies are destroyed, but *new* forms are assumed, *new* properties acquired, and nothing is lost.

How long has the present theory of combustion been received?

It was not *generally* adopted even in France, its birth place, until the year 1787: though the very striking appearances attendant on combustion have been before the eyes of all nations from the beginning, yet many ages elapsed before any *attempt* was made to account for them, or understand either the cause or the effect; until about the year 1665, Philosophers themselves seem to have regarded *fire* as an element that *devoured* every thing it was capable of acting on; but about that period the celebrated Dr. Hooke, well known for his microscopic researches, proposed the first theory of combustion; according to him, there is in air, in salt, in nitre, and several other substances, a something capable of dissolving combustible bodies, which it does with such rapidity, as to occasion the appearance of *light* and *heat*, which he held to be mere *motions;* that combustibles continue burning or *dissolving* until the solvent is saturated, when the process ends of course; a happy conjecture, and not far from the truth, which, however, he had not the means of pursuing.

Did this theory continue to be received until the time of Lavoisier?

No, after being refined upon by Mayow, who carried it to a pitch of extravagance, it was suddenly overturned by the appearance of a new and totally different theory, first proposed by Beecher, but so modified and improved by his celebrated disciple, *Stahl,* that it has been usually called by his name;

he supposed that all combustible bodies contained one common principle to which their inflammability was owing, and of which, by the act of combustion, they were deprived; and to this imaginary principle he gave the name of *Phlogiston.*

How was this theory received?

It had many advocates, as, from the reputation of its author, might naturally be expected, and among them our great Chemist Dr. Priestley; in the language of these Philosophers, a combustible body was said to be *phlogisticated,* and when deprived of their inflammable principle, was dephlogisticated, and of course no longer combustible; they maintained that in all cases of combustion a *loss* was necessarily sustained, and that the body burned had suffered a diminution—Such was their theory, the reverse of which is now found to be true; and Dr. Priestley lived to witness the demolition of the fabric he had so considerable a share in erecting.

What is the peculiar nature of the present theory?

It is now clearly *proved* that the burning body does *not* suffer any *diminution,* but, on the contrary, receives an accession of matter, combustion consisting, *in all cases,* in the union of oxygen with the burning body.

Had Lavoisier the sole merit of this theory?

He was unquestionably its author, but he was much indebted for the materials of which he formed it to other Chemists, and particularly our countrymen Dr. Priestley, Mr. Cavendish, and Dr. Black, whose experiments on the different gases, led the way to that beautiful theory, which that truly great Philosopher established.

You have mentioned the general effect of combustion—can you not give a more particular account of the process?

This cannot be better done than in the words of Dr. Thomson; "When a *stone* or *brick* is heated, it undergoes no change, except an augmentation of temperature, and when left to itself it soon cools again, and becomes as at first; but with *combustible* bodies the case is very different, when heated to a certain degree in the open air, they *suddenly* become *much hotter* of themselves, continue for a considerable time *intensely hot*, sending out a copious stream of caloric and light to the surrounding bodies; this emission, after a certain period, begins to diminish, and at last ceases altogether: the *combustible* has now undergone a most complete *change;* it is converted into a substance possessing very *different properties*, and no longer capable of combustion."

This is indeed an admirable description, but these phenomena might have been observed by a person who had no acquaintance with Chemistry, and do not seem to furnish any proof of the theory above stated—Can you produce an instance in which this is proved?

The same valuable author continues to observe, that "When charcoal is kept for some time at the temperature of 500 degrees, or perhaps a little higher, it kindles, becomes intensely hot, and continues to emit light and caloric for a long time: when the emission ceases, the charcoal has all disappeared, except an inconsiderable residuum of ashes."

Since in this process the whole of the charcoal (the small quantity of ashes excepted) is acknowledged to have disappeared, does not this seem to prove the very reverse of the theory?

It must certainly appear so to an uninformed observer, but it is because the product of the combustion, viz. carbonic acid gas, has been suffered to escape; but if this product be collected, it "is found to *exceed* greatly, in *weight*, the *whole* of the charcoal consumed."

Is this invariably the fact?

Yes, in every instance of combustion the body burnt is found to have increased in weight, while the air in which it has been burned has been deprived of a portion of its oxygen, equal in weight to that which the burnt body has gained; and hence no combustible will burn in air in which any of the same kind of substances has been previously burned, nor will such air support animal life.

Since in every *act of combustion oxygen is united to the burning body, does it not follow that no substance, which does not contain oxygen, can support combustion?*

That certainly does follow.

And are all the bodies which contain oxygen capable of supporting combustion?

Yes, in proper circumstances.

What is meant by proper circumstances?

It is not enough that oxygen be *present;* for unless the body with which it is already combined be disposed to part with it, or the combustible has sufficient force to *compel* it, no combustion can take place; water contains a large portion of oxygen, and yet, instead of *supporting,* it is made use of for *extinguishing* fire; and carbonic acid gas contains *oxygen,* and yet a lighted *taper* plunged into it is immediately *extinguished.*

Can you explain this?

Very easily, by adverting to the laws of chemical affinity, of which, as before said, combustion is an instance; oxygen is never found but in a state of combination, and therefore no combustion can possibly take place, unless the combustible has a stronger affinity for it, than the body with which it is previously combined; when this happens, combustion invariably follows, and not else.

Has not carbonic acid gas, though it contains oxygen, been classed by some chemical authors among the non-supporters of combustion?

Yes, but improperly, as the recent discoveries of Mr. Davy have proved; for though no substance had before been found that would burn in it, because none had an attraction for oxygen sufficiently strong to detach it from the carbon with which it is united in that gas, yet the newly discovered metal, which is the base of potass, and which that admirable Chemist who discovered it has called *potassium*, will burn in it, when heated, with great splendour.

Has any substance been yet discovered, that has so strong an affinity for oxygen, as to detach it from its combination with hydrogen, and burn in water?

Yes, if a globule of potassium be thrown on water, it instantly takes fire, and burns with astonishing rapidity; it likewise burns with equal facility when thrown on ice.

Why is it necessary to heat, or raise the temperature of, some bodies before they will burn?

There is a certain temperature at which combustible bodies are disposed to combine with oxygen, and which varies in different bodies; but, generally speaking, it is necessary to raise the temperature of *all* bodies in order to their being burnt, because it is obvious that all those which are capable of taking fire at the *common temperature* of our *atmosphere*, must be already in a burnt state, and therefore cannot be *burned again* until they have been, as the French Chemists term it, *unburnt*, that is, deprived of their oxygen; this is evidently the case with potass, soda, and the alkaline earths, which Mr. Davy has shewn to be metals, that have undergone combustion, or metallic oxyds; he has had the distinguished honour of succeeding in his endeavours to deprive them of their oxygen, and thus render them again combustible.

Are metals in general combustible, or is this property peculiar to those just mentioned?

Metals in general are combustible, but they usually require their temperature to be *considerably* raised, and to have a plentiful supply of oxygen, in order to their being burnt.

Can you repeat any experiment in illustration of this?

If iron wire be heated red, or if a piece of lighted tinder be attached to it, and it is then plunged into a jar filled with oxygen gas, it will *burn,* throwing out the most brilliant sparks that can be imagined, and, if there is a sufficient supply of oxygen, will continue until the whole of the wire is burnt.

According to the present theory of combustion, it should follow that the iron in this experiment, as well as the charcoal, formerly mentioned, should increase in weight?

Yes, and if it be weighed before and after it has been burnt, it will be found to have done so in the proportion of 35 parts in the 100.

Since metals, which will not *burn in common air, are capable of being burnt in oxygen gas, it seems to follow, that those substances which in common air are combustible, will burn with increased rapidity in that gas?*

This is certainly a natural consequence; charcoal, therefore, which burns with a dull red in common air, burns with great brilliancy in oxygen gas, and, if the bark be made use of, a number of beautiful sparks are thrown off in every direction, attended with a crackling noise; sulphur also burns with an enlarged and much brighter flame in this gas; but the most impressive experiment of this kind is the combustion of phosphorus, for if a bit of it be placed in a spoon, set on fire, and then let down into a jar filled with oxygen gas, the flame instantly appears so enlarged as to fill the whole vessel, and produce a light so intensely brilliant, that the eye can scarcely endure it.

Can no combustible bodies then be burnt without first raising their temperature?

Generally speaking, this cannot happen, for the reasons already given, but there are exceptions to this rule, which must likewise be remembered; potassium furnishes one, and a gas has been before described, namely, the oxy-muriatic, in which even metals, which are certainly not the most combustible substances, will burn without having their temperature previously raised; it is only necessary that they should be reduced into *powder*, or beaten into *leaves*, that the greater surface may be exposed to the action of the oxygen, and they instantly take fire on being immersed in it.

In consequence of this theory of combustion, it must of course follow, that in these cases it is the presence of the oxygen that enables them to take fire—how is it then that the metals, or even the *more combustible bodies, as sulphur and phosphorus, do not take fire in pure oxygen gas?*

It must again be recollected, that oxygen, the sole supporter of combustion, is never found *alone*, but always in a state of *combination* with some other body; even in the state of *gas*, it is combined with *caloric*, which gives it its gaseous form, and when the combustible is *heated* it has a powerful affinity for the oxygen, but none for the caloric with which it is combined, and therefore easily separates them, and takes the oxygen to itself.

How then do they, without being previously heated, take fire in oxy-muriatic acid gas?

Because, from the method of preparing it, this kind of gas has a large quantity of oxygen *forced*, as it were, into its *composition*, the greater part of which it holds by a very weak affinity, and therefore so readily parts with it, that it supersedes the necessity of first heating the bodies in order to their combustion in it.

Then it is to be accounted for, on similar principles, that those combustibles which, when heated to a certain degree, will burn with splendour in oxygen gas, are immediately extinguished on being plunged into water, though water, as well as oxygen gas, contains a large portion of oxygen?

Yes, for the affinity of oxygen for hydrogen, with which it forms water, is double in force to that which it has for caloric, with which it forms gas.

Since combustion cannot be supported without *a constant supply of oxygen, and that oxygen must be, in ordinary cases, furnished by the common air of our atmosphere—does not this prove the necessity of a constant stream of air for the supply of our common fires?*

Yes, this is one among numberless instances of the high importance of chemical knowledge, even as it relates to the most common purposes of life, and this should certainly be always kept in view, both in the construction of our *fire places,* and the management of our *fires,* as all fires will burn well in proportion as the air, which is to furnish the oxygen, is made to pass through the different parts of it.

In what respects do what are called furnaces, *which burn so fiercely, and produce such intense heat, differ in their construction from our common stoves?*

Only in this, that they are so constructed, as not only to admit, but even to *force,* a constant supply of air to *every part* of the burning *fuel,* as no air can ascend the chimney without first going through the fire, and it is for the same reason, that a still greater heat is excited by a large pair of *bellows,* in which case a very considerable quantity of air is not merely *permitted* to enter, but *forced* into actual *contact* with the fuel.

Is the heat produced by the blast of a pair of bellows the most intense that can be produced by art?

No, the greatest degree of heat we are capable of raising, is produced by directing a stream of *oxygen gas* on the combustible body; if even a piece of diamond, which will remain unaltered in the strongest furnace, be placed on a piece of lighted charcoal, and a stream of this gas thrown on it, it cannot long resist a heat so intense, but will speedily be burnt, and, if the experiment takes place in the open air, will totally disappear.

It appears then from all that has been stated, that it is not wholly *owing to the properties of the* combustible *itself, that the process of combustion is sometimes* so *much more rapid and violent than at others?*

Yes, for though some bodies are more combustible, that is, have a stronger affinity for oxygen, than others, and will therefore burn in circumstances in which others will not, yet the rapid combustions which take place in some instances, are principally owing to the quantity of oxygen contained in the supporter of the combustion, and to the facility with which it parts with it.

Can you produce any farther instances in proof of this important truth?

Yes, phosphorus will present us with one; though a very combustible body, yet it only burns with a very feeble flame in the common temperature of our atmosphere; at the temperature of the human body it takes fire, as we call it, and burns more *rapidly,* because its increased affinity for oxygen enables it to detach it more readily from the atmosphere; but it burns with still *greater* rapidity in pure oxygen gas; on this principle it is that nitre is mixed with sulphur in making sulphuric acid, because it contains a considerable portion of oxygen, which it holds by a weak affinity, and therefore readily parts with it to assist the combustion of the sulphur.

Is it not to the presence of nitre that gun-powder owes its great inflammability?

Yes, but there are compounds which take fire more readily, and burn with more rapidity, than gun-powder; the preparation called fulminating mercury is of this nature.

In what manner is this prepared?

By dissolving fifty grains of mercury, or quicksilver, in half an ounce of nitrous acid, with a gentle heat, and afterwards pouring on the solution a quantity of alcohol, or spirit of wine, *double* to that of the acid, if then the flame of a candle be applied for a few seconds, or until bubbles begin to rise to the surface of the fluid, a considerable ebullition will follow, a large quantity of nitrous ether will be evolved, and when the action slackens, a white or grey powder falls to the bottom, the liquid must then be quickly poured off, the powder washed two or three times in clear water, and afterwards dried on a filtering paper, with a heat not greater than that of boiling water.

By what experiment can it be proved *that this powder is more easily inflamed, and its combustion more rapid than that of gunpowder?*

If a lighted paper, or even the flame of a candle, be applied to gunpowder, there is some difficulty in making it take fire, but this powder takes fire before the flame can well touch it; or the superior *inflammability* of this powder may be shewn by mixing it together with gunpowder in a small heap, and holding a lighted paper to the heap, when the mercury will take fire, and every particle of it, though never so intimately mixed with the gunpowder, will be burnt, while the gunpowder will be scattered, but not a single grain of it will take fire.

Then if a train of gunpowder were crossed by another train of fulminating mercury, and the mercury fired, its flame would pass through the gunpowder without firing it?

Yes; but if instead of firing the mercury, you set fire to the gunpowder, it never fails in its explosion to set fire to the mercury also.

This is certainly a very striking experiment—Are there not certain compounds which take fire and explode by percussion?

That is the case with the compound in question, for if a few grains of it be laid on an anvil, and smartly struck with a hammer, it will explode with considerable violence.

Are there not fulminating powders, *as they are called, prepared from other metals besides mercury?*

Yes, from gold and silver, but the *usual* preparations of these metals are so *dangerous*, that it is hardly advisable either to *prepare* or *keep* them; there is, however, a method of preparing a fulminating silver, which is *perfectly safe*, and in point of curious effect inferior to none.

Describe the process.

The *usual* process is similar to that by which fulminating mercury is prepared, but a far *better way* is to take *lunar caustic* (nitrate of silver) as used by the surgeons, 25 grains, and having mixed *gradually* half an ounce of nitrous acid with one of alcohol, or spirit of wine, put the whole into a Florence flask, and having, as in the process for making fulminating mercury, just warmed it until the air bubbles begin to rise, proceed in the same manner, washing and drying the white powder which falls down, and which is the fulminating silver; great care must be taken in drying it, that no spark of fire comes near it.

What are the curious properties of this compound?

If a very small quantity of this powder be held to the candle, or a piece of lighted paper be put to it, it will instantly explode with a smart noise, and a quantity equal to the size of a *pea* will produce an explosion full as loud as the ear can well bear.

Will this powder, like the last mentioned, explode by percussion?

No, but, on the other hand, it has a very curious property, which the fulminating mercury has not, for if it be laid on a piece of *quartz, flint, glass,* or any stone containing *silex,* and be *pressed* or *rubbed* with another piece of quartz, &c. or the point of a *penknife,* it instantly explodes; it is still more singular, that it will explode when wetted, as freely as when it is dry, and even under water.

Since water will not, except in the case of the new metals, part with its oxygen to a combustible body—can combustion in any other instance be maintained under water?

Water extinguishes a burning body when plunged into it, merely by cutting off its communication with the oxygen of the atmosphere, just in the same manner as a glass or any other vessel would do, under which no combustible, not even phosphorus itself, can burn after it has consumed all the oxygen which the vessel contained; but if there be a supply of oxygen, the combustible will burn as freely *under* the *water* as it will in the open air, thus several compositions with nitre will burn under water; but there are two chemical experiments by which this may be shewn in a very striking manner.

What are the experiments by which so striking a fact can be illustrated?

If a small piece of phosphorus be placed at the bottom of a wine glass filled with *hot* water, and a stream of oxygen gas be thrown on the phosphorus, by means of a bladder with a small pipe attached to it, it will take fire and continue to burn as long as the gas is supplied, or until it is wholly consumed; or, instead of this, let a piece of phosphorus be put at the bottom of an empty glass, together with some oxy-muriate of potass, and then let the glass be gently filled with cold water, so as not to *displace* the *salt*, then, by means of a glass tube or funnel, let a small quantity of sulphuric acid be let down on the phosphorus, and the latter will immediately *take fire*, and burn *under* the water, the oyx-muriate supplying the oxygen necessary for its combustion.

APPENDIX.

IN the foregoing pages expressions frequently occur, which, though perfectly familiar to the Chemist, must be in great measure, if not altogether, unintelligible to those who take up, for the first time, the subject of Chemistry; for instance, though every Chemist knows what is meant by "collecting a gas over water in the usual way," yet it is scarcely possible for any person, however otherwise intelligent, who has never seen the process, or a description of it, to comprehend its nature; and though an explanation has been in one or two places attempted, where a degree of awkwardness was felt at the time, yet this could not always be done, and if it had been in every instance attempted, it would perhaps have been attempted to little purpose by words only, it was therefore thought necessary, especially considering the persons for whom this is principally written, to have recourse to figures, and to subjoin the following

EXPLANATION OF THE PLATE.

Fig. 1, in the upper compartment, represents a patent lamp, over which is a retort, fig. 2, if the lamp is separate from the ring which supports the retort, the latter should be made to slide up and down, so as to be placed at different distances above the flame of the lamp, according to the degree of heat required; as it is sometimes requisite to remove the lamp without any trouble or loss of time, it is perhaps more desirable to have it separate, as in the figure, than to have the lamp and the ring both slide on the same stand; the retort represented in the figure has a stopper at the top, and is therefore called a tubulated retort, this addition adds but little to the expence, and will in many cases be found very convenient; retorts are made of various materials, those to be used in the fire are of earthen ware or iron, but those which are used over a lamp are of glass, and being blown very thin at the bottom are not often broken by the heat of the lamp, even when suddenly applied; when used, if any gritty substance has been poured in, as in the making oxymuriatic acid, it will be necessary to work the stopper round a little, that it may not, by any particle lodged in the neck, be kept from being air tight, and if a little tallow or soft pomatum is rubbed on the stopper, it will often be of great service in keeping these, or any similar joinings, air tight.

Fig. 3 represents the balloon receiver, so called from its round form, into the neck of this the beak of the retort is inserted, it is then to be made fast, so as not to shake about, by pressing some slices of cork between the neck of the receiver and the beak of the retort, and made air tight by covering with lute, hereafter described; when only this receiver is used, the top is closed by loosely dropping in the stopper, fig. 4; in the formation of gases, however, an apparatus consisting of one or more of Woulf's bottles, added to the first receiver, is exceedingly serviceable; one of these is represented fig. 5, it has three necks, by one of which it is connected with the first receiver by means of a bent glass tube, fig. 6, one leg of which is luted into the top of the receiver, which it enters but a little way, while the other leg, as represented, is luted into one of the necks of the bottle; if any fluid is to be impregnated, as in forming the oxy-muriate of potass, this leg of the bent tube must be continued below the surface of the fluid, so that the gas, which, after filling the balloon, comes over into the bottle, may pass through it, as represented by the dotted lines in the figure; in the middle neck of Woulf's bottle a glass tube, fig 7, about two foot long, is inserted, the lower end of which is likewise below the surface of the fluid; if only one of Woulf's bottles is used, the remaining neck, or that farthest from the first receiver, is to be closed by a stopper; if two or more are employed, they are to be connected with each other by bent tubes, in the same manner as that in the plate is connected with the first receiver; the peculiar advantage of this apparatus is easily explained, for if the first receiver only is used, the stopper is frequently thrown out, or if not loose, the receiver is in danger of bursting by the sudden production of an elastic fluid; whereas, when the Woulf's bottles are employed, if any extra quantity of gas comes over, the fluid in the bottle, by rising in the tube, affords it room, or even permits the superfluous portion of it to escape, without endangering the apparatus; the top of the tube should be furnished with a kind of bason, as represented at fig. 7, to prevent the loss of a part of the fluid, when driven up above the top of the tube—a common four-ounce vial with a hole in the bottom, and cemented by its mouth to the top of the tube, answers this purpose admirably well.

In the middle compartment of the plate the pneumatic trough, or water bath, is represented, fig. 1; this may be made of tin or wood, and of any size or shape which may suit the operator; but wood, if lined with lead, is heavy, and if not lined, is liable to leak, tin is therefore preferable when the vessel is made for chemical purposes, though any wooden or earthen vessel, that will admit of placing a shelf in it, and immersing a bottle under it, may be made to answer the purpose; the celebrated Dr. Priestley began his brilliant career with a washing tub; the most convenient size is perhaps about 15 inches long, 7 wide, and 13 deep, this will admit of a shelf at one end, and leave sufficient room to fill and invert a common quart wine bottle, which is frequently wanted: fig. 2 is a shelf in the inside of the trough, this should be so far below the edge of the trough as to admit the water to rise about an inch above it; in the middle of the shelf there is a hole for the gas to pass through when any vessel is to be filled, which is to be done thus—the vessel, suppose a bell glass receiver, like that fig. 3, is to be plunged under the water in the trough, with its mouth upwards, and when filled with it, is to be turned upright, and then raised and placed over the hole in the shelf, as represented in the figure, in doing this care must be taken not to raise it higher than is necessary for putting it on the shelf, for if raised above the surface of the water in the trough, that in the receiver will all fall out; when the receiver is to be filled with any kind of gas that has been previously kept in a corked bottle, the bottle is to be uncorked while its mouth is under water, the mouth is then to be brought under the hole in the shelf, and gradually raised until it is upright, or nearly so; in this case the water in the trough will force its water into and fill the bottle, while the gas will rise out of it, and passing through the hole in the shelf, will displace the water in the receiver and occupy its place; now, as the water sinks in the receiver in consequence of the gas occupying its place, it will always be seen how much gas has been admitted into the receiver, and when it is full, though the gas itself should be, as in most cases it is, invisible; a kind of flat funnel should be fixed underneath the hole in the shelf, otherwise, unless the mouth of the bottle is held very exactly under the hole, some of the gas will be liable to escape without passing into the receiver; it is obvious that during these operations the water in the trough will rise and fall, and as it must never, for the reason before mentioned, be suffered to sink so low as the shelf on which the receiver stands, it will be found very convenient to have a spout at the other end of the trough, either with or without a cock, as represented fig. 6, this will keep the water from overflowing, and if a vessel of any kind is put under to receive it, it may be poured in again when wanted.

Fig. 4 represents a gas bottle, with a bent tube, 5, ground into its neck, this is exceedingly convenient on many occasions, and is used thus—if it were required to fill a receiver with hydrogen gas, the bent tube, 5, being taken out, the filings and water are poured into the bottle, the proper quantity of sulphuric acid is then added, and the tube being quickly put into the bottle, is made to pass under the shelf, so that its mouth may be directly under the hole, when the gas as it is formed in the bottle will rise and pass through the tube into the receiver, 3; this apparatus is exceedingly convenient for preparing carbonic acid gas, in which of course marble or chalk must be used, instead of iron or zinc filings; when the receiver is full, it must be removed by sliding it into a saucer held under the water, and taken out with the water in the saucer, which, by surrounding the bottom of the receiver, will keep the gas from escaping; if a bottle is to be filled with gas for the purpose of keeping, it must be filled with and inverted under the water, in the same manner as described for the receiver, and when raised, held with its mouth over the hole in the shelf, and when full, corked under water. N. B. The gas bottle represented in the figure is tubulated, or furnished with a stopper, but this, though sometimes convenient, is by no means necessary, and at the same time enhances the expense, especially as they are very liable to be broken, if great care is not taken in using them.

In the lower compartment of the plate different apparatus are represented; fig. 1 is a glass flask or matrass, as it is called, this is useful for any purpose where the heat of a patent lamp is to be applied, a common oil flask, which may be purchased at a very trifling expense, will be found to answer all these purposes incomparably well, as they bear very well the sudden application of heat or cold: fig. 2 represents a crucible or melting pot—those generally used are made of earthen ware or black lead, and will bear a most intense heat: fig. 3 represents a receiver with an open top, such as is used for the combustion of different substances in oxygen or oxymuriatic acid gas; where a small expense is not an object, these have a stopper ground into the top, but a cork if well fitted will answer the purpose; these receivers have frequently a brass cap at the top, into which a stop-cock is made to screw, for the purpose of transferring the gas into a bladder, as represented in the figure, where *5* is the bladder, 4 the stop-cock, one end of which is inserted into the neck of the bladder, and the other screws into the brass cap; when the gas is to be transferred from the receiver into the bladder, the stop-cock being open all the air is to be carefully squeezed out of the bladder, and the cock then closed to prevent its re-entering, it is then to be screwed into the top of the receiver while immersed under water, the receiver is then to be raised on to the shelf, and filled as before directed; when full, the stop-cock is to be opened, and the receiver gradually pressed down into the water, which rising into it will force the gas up into the bladder; if the contents of one receiver are not sufficient for the purpose, the stop cock much now be closed as before, and the same process repeated, until there is a sufficient quantity of gas in the bladder, when, the stop-cock being closed, it may be taken off, and reserved for use. If a receiver of this kind, with stop-cock, be not at hand, the bladder may be filled by tying it, wet, on to the tube of the gas bottle, or by putting the ingredients, from which the gas is to be made, into a common vial, and either tying the bladder on to the neck of the vial, or to a pipe inserted into a cork in the vial; the principal inconvenience attending these methods is that the acid frequently froths up, and flows over the vial, and of course corrodes and spoils the bladder, which is not liable to happen when the receiver and stop-cock are used; in short, when expense is not an object, neatness, not to say

elegance of appearance, will naturally be consulted, and where it is, the ingenious practitioner will easily discover that a large and complicated apparatus is in very few instances absolutely necessary; he may indeed console himself with a remark made, in an introductory lecture, by the learned and entertaining Lecturer of the Royal Institution, that "Many experiments of the first importance have been performed, and discoveries made by Chemists who had no laboratory, and whose whole apparatus has consisted of little more than a few apothecaries' vials, some tobacco pipes, and a washing tub."

LUTES.

It has been mentioned, that it is frequently necessary to employ lutes, in order to render the joinings of chemical vessels air-tight; there are different kinds for different purposes; when no great heat is required, any soft kind of paper with common paste will answer the purpose; where there is no heat, a cement of rosin and bee's-wax, or rosin only, will answer, as it will stand the corrosive acids; but when great heat is required, dry clay beat up with liquid oil is perhaps one of the best; for many purposes common glazier's putty will answer very well.

TABLE OF SIMPLE AFFINITY.

OXYGEN.

- Carbon
- Charcoal
- Manganese
- Zinc
- Iron
- Tin
- Antimony
- Hydrogen
- Phosphorus
- Sulphur
- Arsenic
- Nitrogen
- Nichel
- Cobalt
- Copper
- Bismuth
- Caloric
- Mercury
- Silver
- Gold
- Platina
- Muriatic acid

CARBON.

- Oxygen
- Iron
- Hydrogen

NITROGEN.

- Oxygen
- Sulphur
- Phosphorus
- Hydrogen

HYDROGEN.

- Oxygen
- Sulphur
- Carbon
- Phosphorus
- Nitrogen

SULPHUR, PHOSPHORUS.

- Potass
- Soda
- Iron
- Copper
- Tin
- Lead
- Silver
- Bismuth
- Antimony
- Mercury
- Arsenic

POTASS, SODA, & AMMONIA.

- *Acids*, Sulphuric
  - Nitric
  - Muriatic
  - Phosphoric
  - Fluoric
  - Oxalic
  - Acetic
  - Nitrous
  - Carbonic
  - Prussic
- Oil
- Water
- Sulphur

BARYTES.

- *Acids*, Sulphuric
  - Oxalic
  - Fluoric
  - Phosphoric
  - Nitric
  - Muriatic
  - Acetic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur
- Phosphorus
- Water
- Fixed oil

LIME.

- *Acids*, Oxalic
  - Sulphuric
  - Phosphoric
  - Nitric
  - Muriatic
  - Fluoric
  - Acetic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur
- Phosphorus
- Water
- Fixed oil

MAGNESIA.

- *Acids*, Oxalic
  - Phosphoric
  - Sulphuric
  - Fluoric
  - Nitric
  - Muriatic
  - Acetic
  - Sulphurous
  - Nitrous
  - Carbonic
  - Prussic
- Sulphur

ALUMINE.

Acids, Sulphuric
Nitric
Muriatic
Oxalic
Fluoric
Phosphoric
Acetic
Sulphurous
Nitrous
Carbonic
Prussic

SILEX.

Fluoric acid
Potass

SULPHURIC ACID, AND PRUSSIC.

Barytes
Strontites
Potass
Soda
Lime
Magnesia
Ammonia
Alumine

PHOSPHORIC ACID.

Barytes
Strontites
Lime
Potass
Soda
Ammonia
Magnesia
Alumine
Silex

CARBONIC ACID.

Barytes
Strontites
Lime
Potass
Soda
Magnesia
Ammonia

NITRIC ACID.

Barytes
Potass
Soda
Strontites
Lime
Magnesia
Ammonia
Alumine

MURIATIC ACID.

Barytes
Potass
Soda
Strontites
Lime
Ammonia
Magnesia
Alumine

FLUORIC ACID.

Lime
Barytes
Strontites
Magnesia
Potass
Soda
Ammonia
Alumine
Silex

ACETIC ACID.

Barytes
Potass
Soda
Strontites
Lime
Ammonia
Magnesia
Alumine

ALCOHOL.

Water
Ether
Volatile oil
Alkaline Sulphurets

FIXED OIL.

Lime
Barytes
Potass
Soda
Magnesia
Alumine

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FINIS.

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